Management of Secondary Treatment Trains

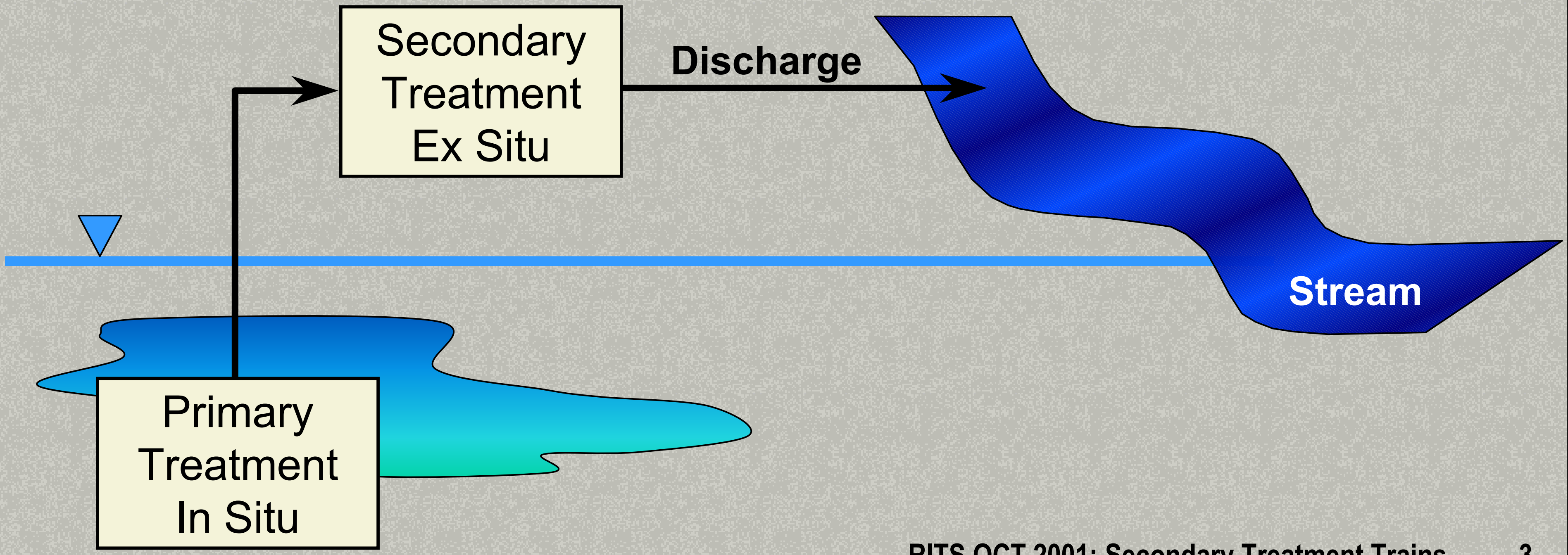
Malcolm Pirnie, Inc.

Presentation Overview

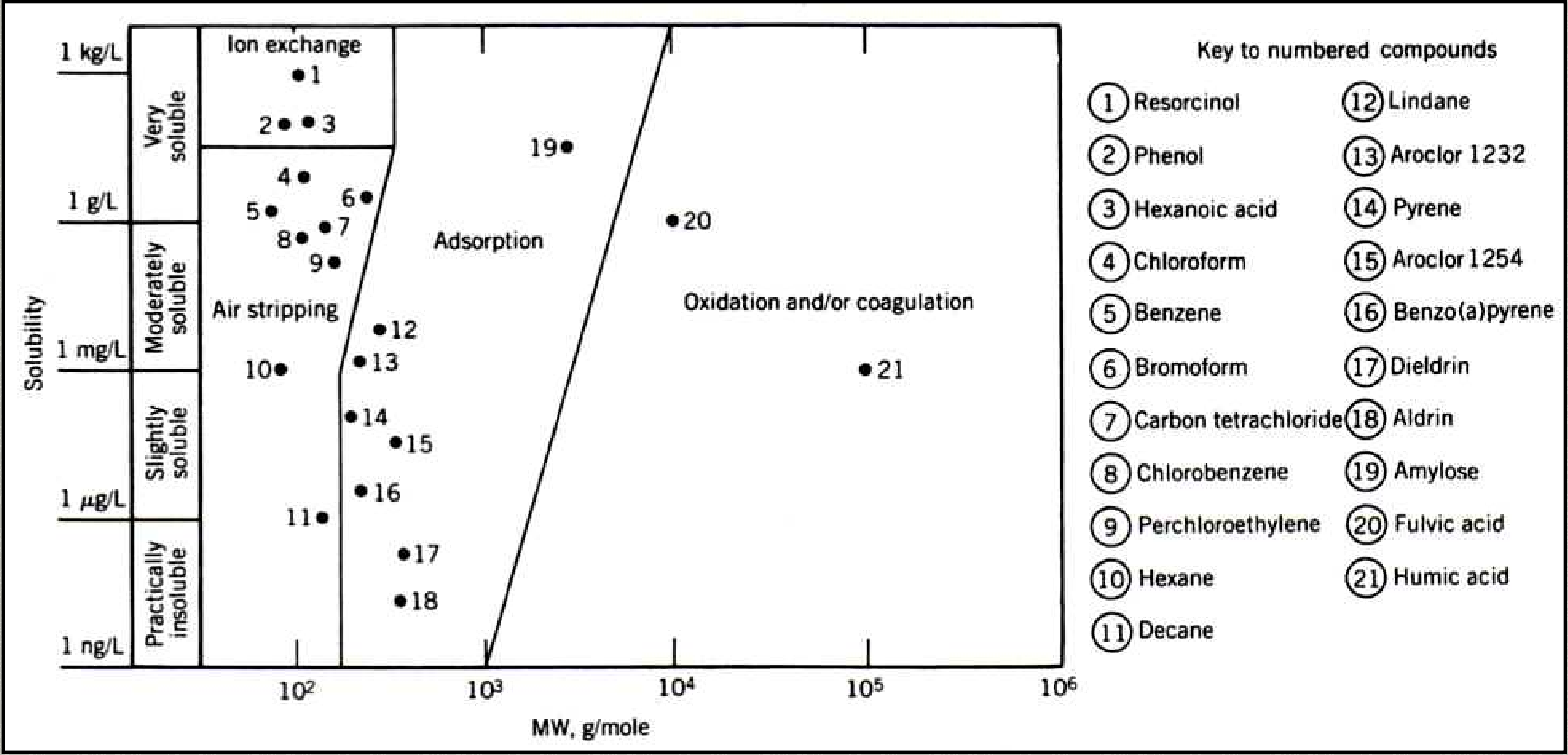
- Background
- Secondary Treatment Trains
  - Air Stripping
  - Granular Activated Carbon (GAC)
  - Advanced Oxidation Processes (AOPs)
  - Biological Treatment
- References
- Points of Contact

Secondary Treatment: Definitions

Destruction or removal of contaminants from remedial waste streams prior to discharge of treatment effluent.



Secondary Treatment Train Process Selection



Environmental Technologies Design Options Tool (ETDOT™)

ETDOT™
(available)

- AdDesignS™ — **Fixed bed adsorber performance; contains extensive adsorber, adsorbent, and isotherm databases**
- ASAP™ — **Packed tower, surface, and bubble aeration systems**
- StEPP™ — **Provides physical property data and estimates**
- AdOx™ — **Advanced oxidation processes (AOPs); contains second-order rate constant database**

http://es.epa.gov/ncerqa_abstracts/centers/cencitt/year3/process/hand2.html

Water Quality Impacts on Selection (Inorganics)

- **Hardness:** Causes scaling of air stripper.
  - >50 mg/L tray air stripper; >300 mg/L tower air stripper
- **Turbidity:** Decreases UV irradiation in AOPs.
- **Alkalinity:** Carbonate and biocarbonate ions scavenge hydroxyl radicals to create carbonate radicals in AOPs.
- **Nitrates/Nitrites:** (>1 mg/L) Adsorb UV light in the range of 230-240 mm and 300-310 mm.
- **Phosphates/Sulfates:** Have potential to scavenge hydroxyl radicals in AOPs.

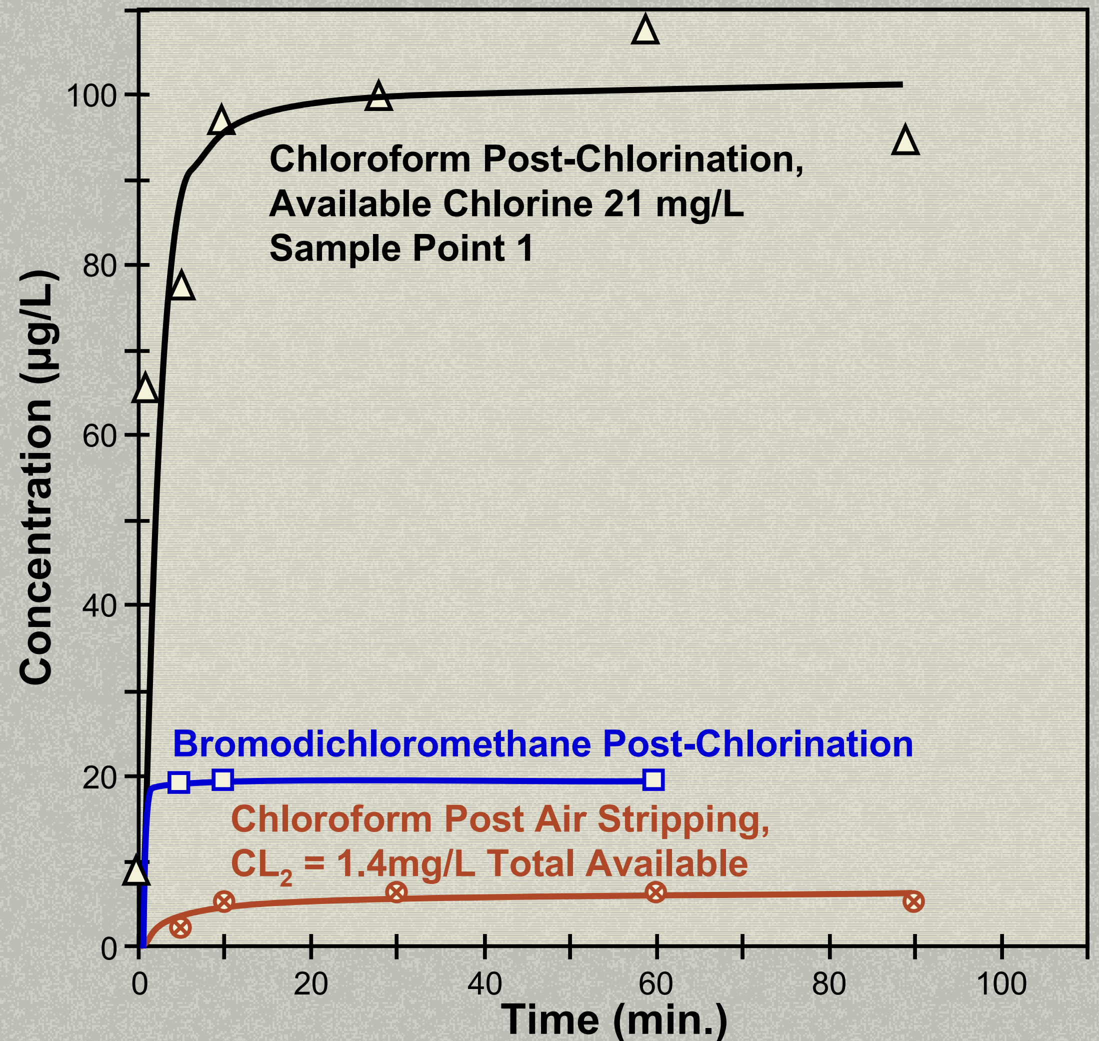
Water Quality Impacts on Selection (Metals)

- **Iron:** (>3 mg/L) Fouls air strippers and advanced UV oxidation systems.
- **Iron, Copper, Manganese:** Forms organic complexes in advanced oxidation systems.
- **Manganese:** Forms permanganate in AOPs.
- **Arsenic and Mercury:** Exist in organic forms.
  Can use capacity in activated carbon systems and impact performance of advanced oxidation systems.

Water Quality Impacts on Selection (Organics)

- **NOM:** Natural organic matter reduces adsorption capacity of GAC. Will scavenge hydroxyl radicals in AOPs.
- **TOC/SOCs:** Total organic carbon/synthetic organic compounds can reduce GAC adsorption capacity. Will scavenge hydroxyl radicals in AOPs.
- **Oil and Grease:** Will foul air stripper systems, and will reduce adsorption capacities in GAC systems. Will scavenge hydroxyl radicals in AOPs.

Post-Chlorination and Post-Stripping Formation of Trihalomethanes (THMs)



Presentation Overview

- Background
- Secondary Treatment Trains
  - Air Stripping (AS)
    - Definition
    - Types of AS Systems
    - Design Calculation
    - Design Variables
    - Advantages/Disadvantages
    - Costs
    - Case Studies
  - Granular Activated Carbon (GAC)
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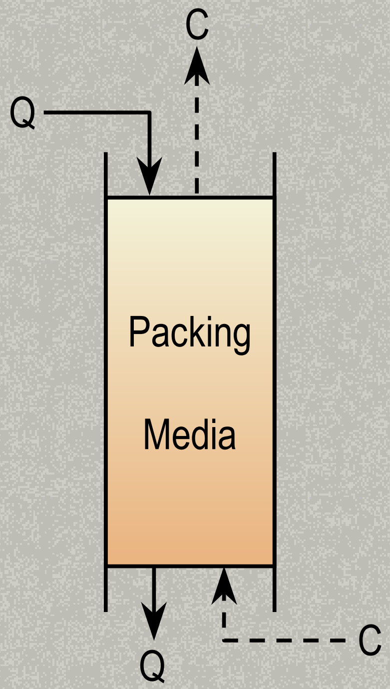
Air Stripping

Definition

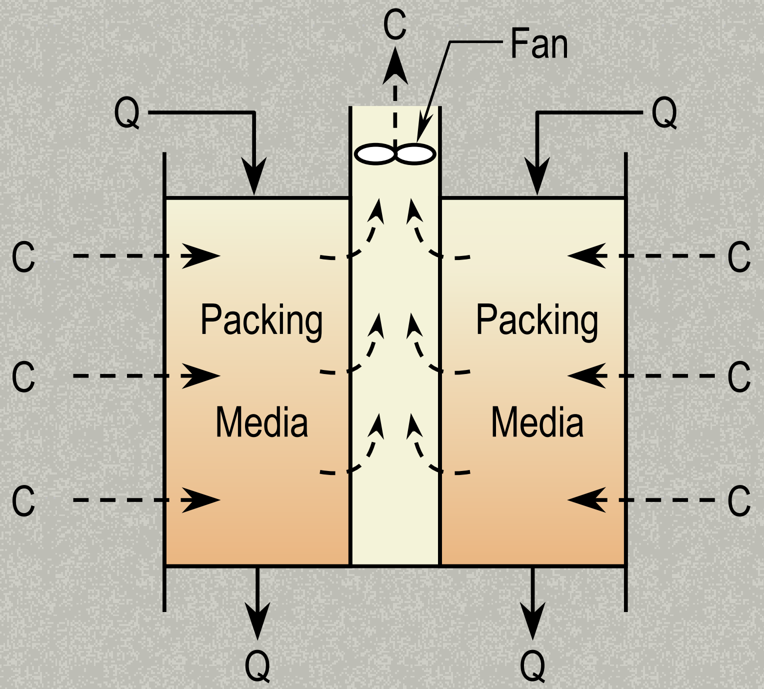
- Mass transfer of compounds from an aqueous stream to a gaseous stream.

Commonly Used Types of Air Stripping Systems

Packed Towers



Countercurrent Flow

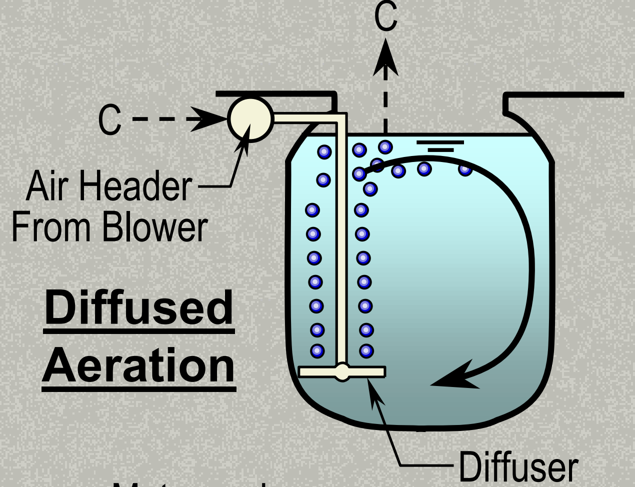


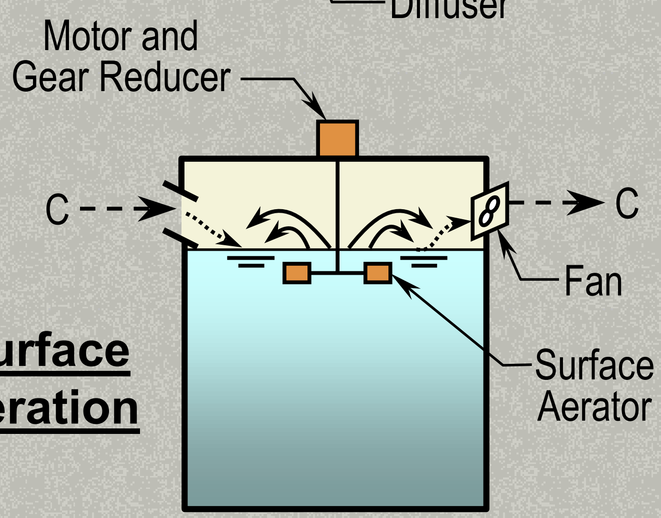
Cross Flow

Packed Tower

Commonly Used Types of Air Stripping Systems (cont.)

Aeration Tanks





Low Profile

Design Calculations – Towers

$$Z = \frac{\overline{Q}}{(1-A)K_La} \ln\left(A + (1-A)\, C_o \big/ C_e\right)$$

Z = Height of tower, ft

$\overline{Q}$ = Hydraulic load, gpm/ft^2

K_La = Mass transfer coefficient

C_o = Initial/influent concentration, mg/L

C_e = Effluent concentration, mg/L

A = Adsorption coefficient

Design Calculations – Towers (cont.)

$$\%R = \left(1 - e^{b}\right) \Big/ \left(A - e^{b}\right)$$

$$b = \frac{K_L a Z (1 - A)}{\overline{Q}}$$

&

$$A = \frac{Q}{GH}$$

Q = Liquid Flow
G = Gas Flow
H = Henry's Law Constant

Design Considerations – Towers (cont.)

Parameter	Effect of Increasing (?) Parameter on Operations and Cost, Assuming No Change in Tower Design	Effect on Increasing (?) Parameter on Tower Design, Assuming Removal Efficiency is Maintained
Liquid Loading Rate	? Removal Efficiency ? Cost	? Tower Height (HTU)
Air/Water Ratio	? Removal Efficiency ? Cost	? Packing Volume
Water Temperature	? Removal Efficiency ? Heating Cost ? Henry's Law Constant	? Packing Volume
Henry's Law Constant	? Removal Efficiency	? Packing Volume (AWR)
Packing Type and Size	? Size ? Removal Efficiency	? Size ? Packing Volume ? Pressure Drop

Advantages/Disadvantages

Advantages	- Ease of operation - Computer models available for design - Low capital and operating costs
Disadvantages	- Corrosion - Scaling - Iron fouling - Biological fouling - Off-gas treatment - Aesthetics (tower)

Costs

MTBE Removal

Flow (gpm)	Capital ($1000)	Annual (O&M $1000)
60	$50-100	$50-60
600	$200-700	$80-280
6,000	$2000-7000	$250-1400

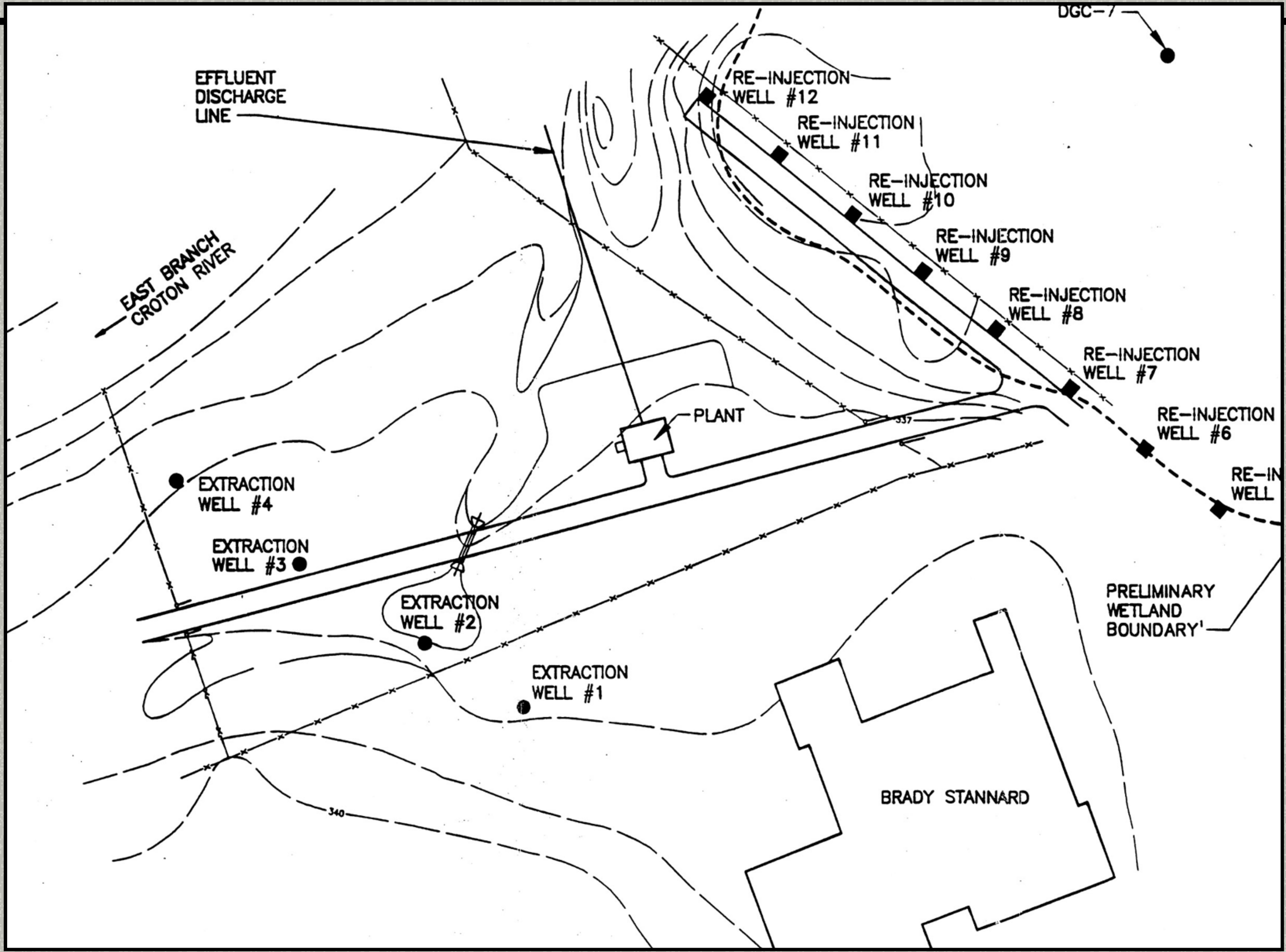
High Flow Case Study – Brewster, NY

Problem:
Design an air stripper (tower) to treat total volatile organic compounds (VOCs) of 6,000 ppb, including TCE (120 ppb), PCE (5,600 ppb), VC (20 ppb), and 1,2-DCE (210 ppb). (Flow = 50 gpm)

- Treated effluent to be reinjected back into groundwater regime for use as drinking water by Village of Bedford, NY (Beneficial Reuse).
- Fee offered design consultant was $2 million to design, build, and startup.

Site Layout

High Flow Case Study – Brewster, NY



Air Stripping Tower

High Flow Case Study – Brewster, NY

- TCE: 120 ppb
- PCE: 5,600 ppb
- VC: 20 ppb
- 1,2-DCE: 210 ppb
- Total VOCs: 6,000 ppb

Flowrate (Q) = 50 gpm
Design/Build = $2.0M
O&M = $75K/yr

Summary

High Flow Case Study – Brewster, NY

Remedy

- Discharge to stream instead of reinjection
- Wetlands study to assure no impact
- Roto-rooter effluent pipe every 6 months
- Clean stripper media or change annually

Low Flow Case Study – Cincinnati Gear

- 1,1-TCE: 1,400 ppb
- 1,1-DCA: 760 ppb
- 1,2-DCA: 39 ppb
- 1,2-DCE: 3,400 ppb

Flowrate (Q) = 6.5 gpm
Capital = $107,500
O&M = $18,500/yr

Summary

Low Flow Case Study – Cincinnati Gear

- System oversized to accommodate future flows and loads.
- System is operating successfully as designed, and meeting projected annual operating costs over the past 3 years of operation.
- Requested system shutdown to evaluate post-remediation conditions of groundwater. If successful, site closure will be achieved 2 years early.

Air Stripping Summary

- Need to understand water chemistry and site hydrogeology for effective overall design.
- Can be a cost-effective pump-and-treat solution for remediating VOC-contaminated groundwater.
- Need to identify any pre-treatment that may be necessary (hardness and iron removal to minimize scaling and fouling).
- Determine need for ancillary process to protect against biofouling.
- Consider post-treatment water chemistry.

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- Definition
- Source
- Design Calculations
- Design Considerations
- Variables & Design Parameters
- Advantages/Disadvantages
- Costs
- Case Studies

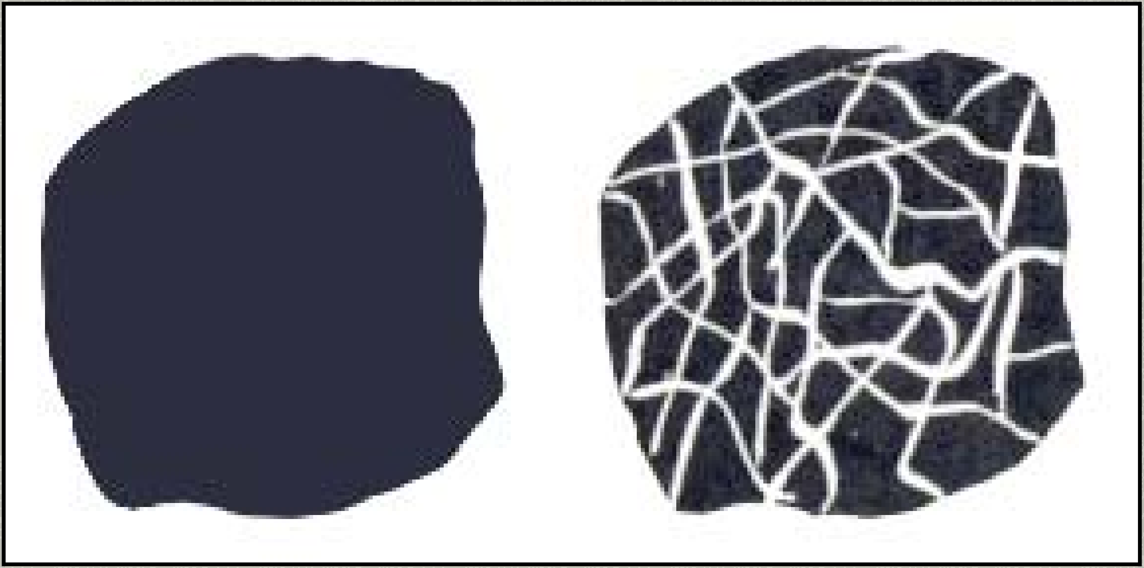
Granular Activated Carbon

Definition

- Intermolecular attraction between molecules of a dissolved chemical (adsorbate) and the GAC (adsorbent) surface results in adsorbtive forces that physically attract the adsorbate to the GAC as water passes through a vessel.

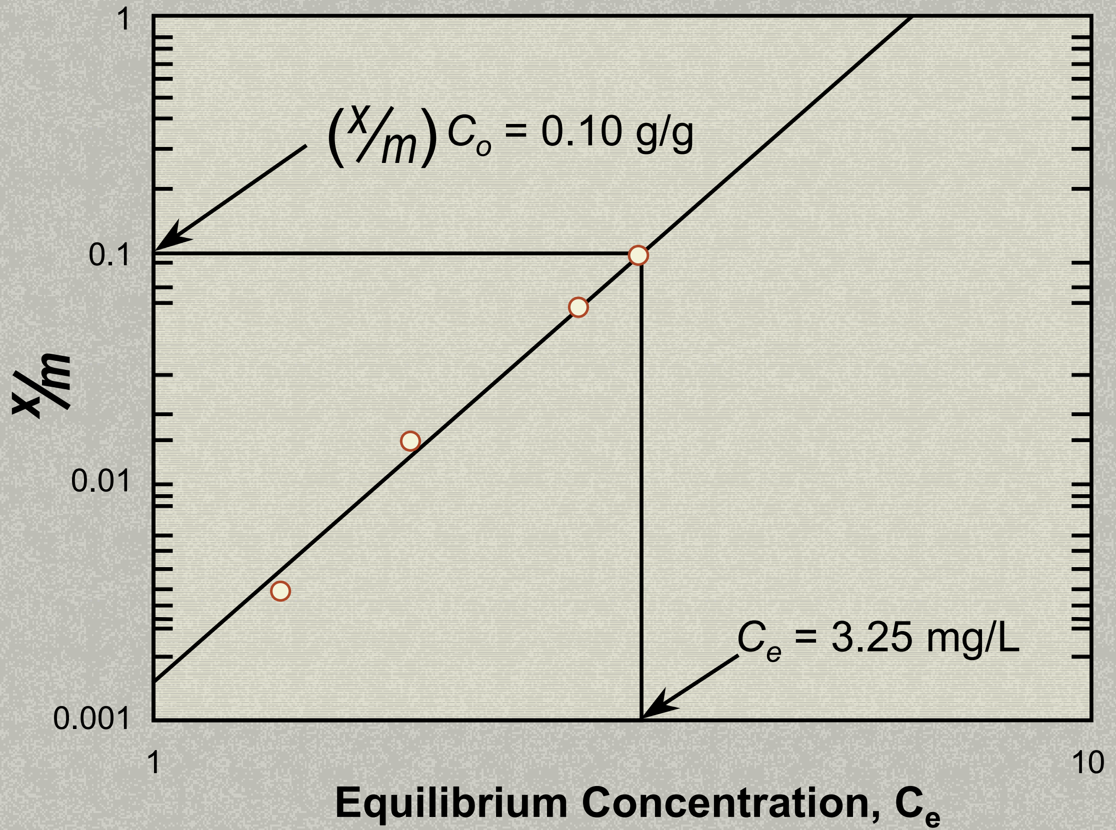
GAC – Source

- Bituminous Coal
  - $1.05 – $1.20/lb
- Coconut Shell
  - $0.65 – $1.35/lb
- Petroleum Coke
- Wood
  - $0.085/lb
- Peat



Produced by grinding, roasting, and activating the source materials with high-temperature steam.

GAC – Design Calculations



Freundlich Isotherm

$(x/m) = K_f C_e^{1/n}$

(x/m) = Amount of adsorbate adsorbed per unit weight of adsorbent

C_e = Equilibrium concentration of adsorbate in solution after adsorption

K_f, n = Empirical constants

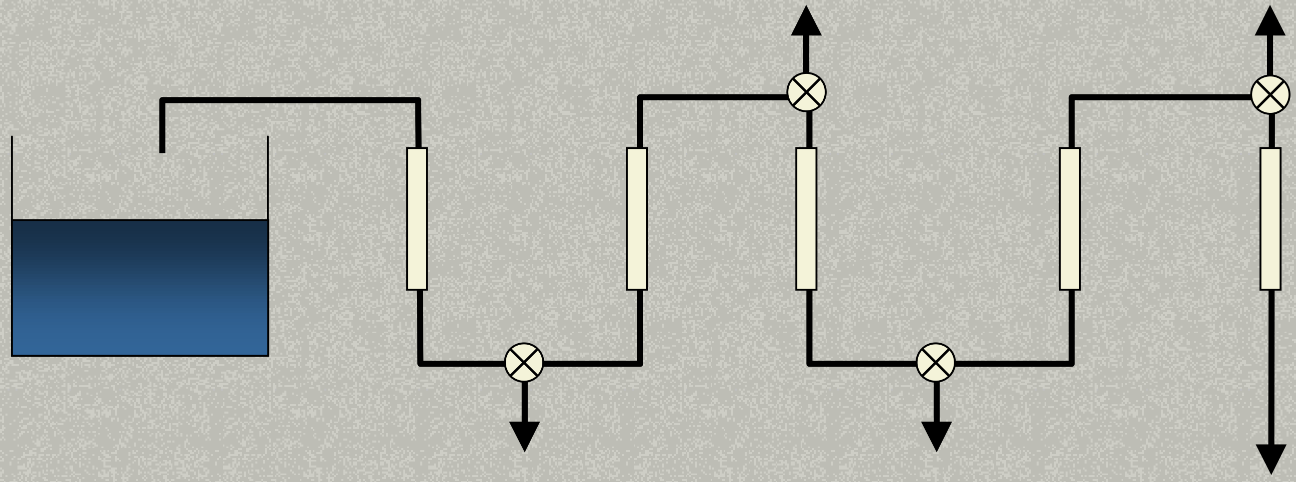
Freundlich Isotherm Jar Test

GAC – Design Calculations (cont.)

$$t_b = \frac{(x/m)_b M_c}{Q[C_i - (C_b/2][8.34\ \text{lb/Mgal} \cdot (\text{mg/L})]}$$

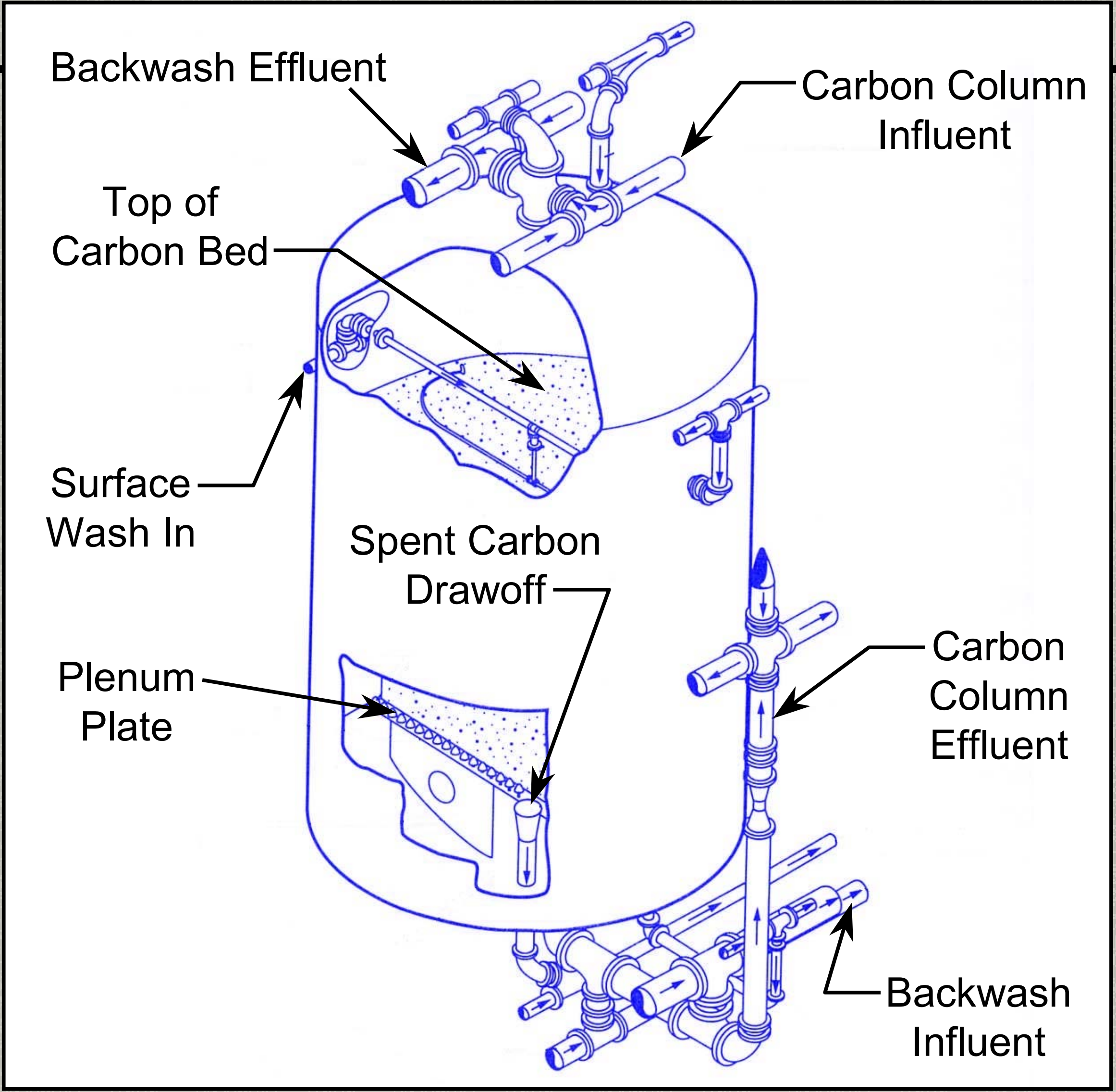
M_c = mass of carbon in the column, lb or g
Q = flowrate, Mgal/d
C_i = influent organic concentration, mg/L
C_b = breakthrough organic concentration, mg/L
t_b = time to breakthrough, d

Dynamic Testing Using Rapid Small-Scale Column Test (RSSCT)



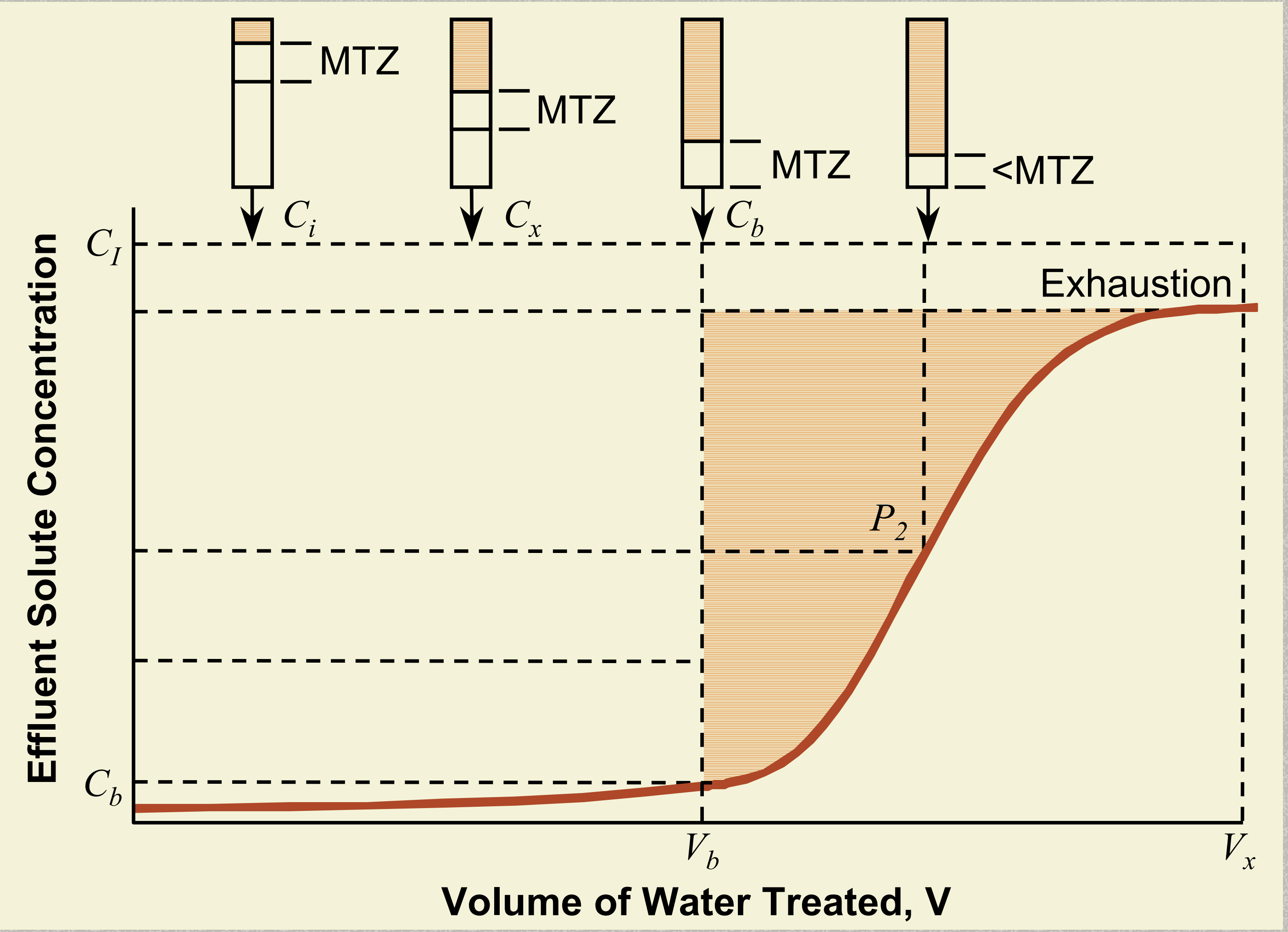
- Dynamic testing is performed with a set of GAC columns connected in series.
- Samples taken at the effluent of each column allow the development of concentration breakthrough curves.
- Data is used for full-scale design.

Design Considerations



Design Considerations (cont.)

i = Initial
x = Time x
b = Bed
I = Influent
MTZ = Mass Transfer Zone



Variables and Design Parameters

- GAC type
- Background water quality
- Pretreatment
- Carbon changeout requirements
- Backwash requirements

GAC Advantages/Disadvantages

Advantages

- Reliability
- Flexibility
- Ease of Implementation
- No off-gas treatment
- Low capital installation costs

Disadvantages

- Impact of other soluble organic compounds (SOCs)
- Desorption
- Operating costs
- NOM

GAC Costs

MTBE Removal

Flow (gpm)	Capital ($1,000)	Annual (O&M $1,000)	Unit Costs ($/1,000 gal)
60	$150-234	$61 – 127	$2.30 – 4.43
600	1,000	161 – 665	$0.77 – 2.37
6,000	6,000	1,000 – 6,500	$0.50 – 2.22

Case Study – Fried Industries, NJ

Record of Decision (ROD)

- VOC contamination
  - Groundwater
- Pump-and-treat with GAC

1,1,1-TCA	15 ppb
1,1-DCA	670 ppb
Toluene	280,000 ppb
Xylene	49,000 ppb
1,2,4-TMB	55,000 ppb

Case Study – Fried Industries, NJ (cont.)

Conventional Pollutants

Chemical Oxygen Demand (COD) 1,480 ppm
Biological Oxygen Demand (BOD) 330 ppm
Total Organic Carbon (TOC) 323 ppm

Negotiate significant difference from ROD

Case Study – IBM

TOC	2 ppm
1,1,1-TCE	20 ppb
PCE	20 ppb
DCE	20 ppb
TSS	10 mg/L

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  - Advanced Oxidation Processes (AOP)
    - Definition
    - Oxidants/Process
    - Water Quality Impacts
    - Advantages/Disadvantages
    - AOP Processes
    - Costs
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Advanced Oxidation Processes (AOP)

Definition

- The transfer of one or more electrons from an electron donor (reductant) to an electron accepter (oxidant), which has a higher affinity for electrons (the end products of complete oxidation of organic compounds are CO_2 and H_2O).

Oxidants

Compound	Oxidation Potential
Fluorine	2.85 ev
Hydroxyl radicals (-OH)	2.70 ev
Ozone	2.07 ev
Chlorine	1.49 ev

AOP Technologies

Established

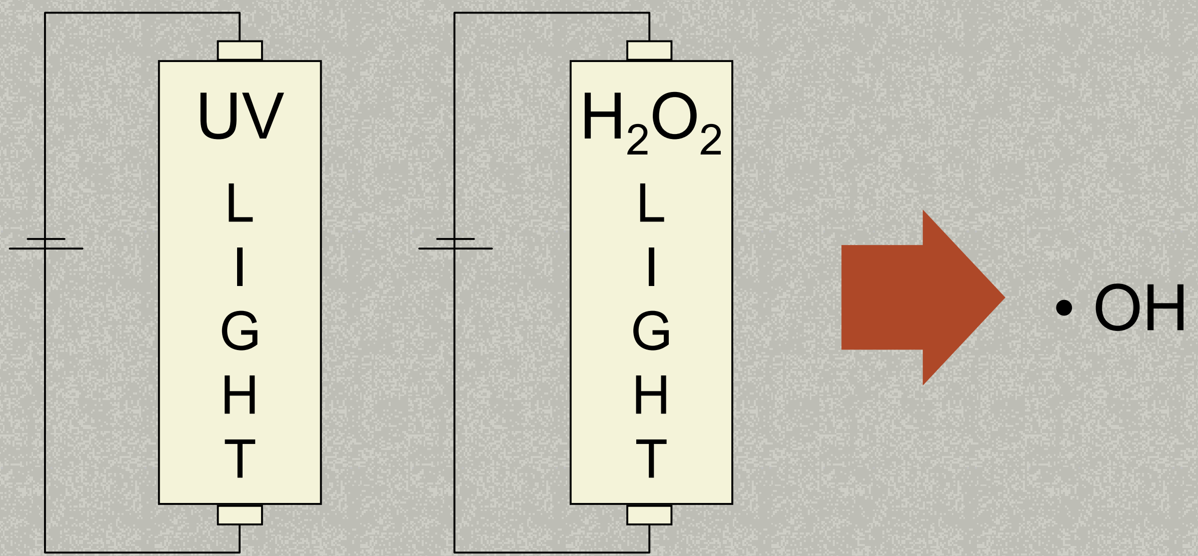
- Hydrogen Peroxide/Ozone
  - H_2O/O_3
- Ozone Ultraviolet Irradiation
  - O_3/UV
- Hydrogen Peroxide/ Ultraviolet Irradiation
  - H_2O_2/UV

Emerging

- High Energy Electron Beam Irradiation (E-beam)
- Cavitation (Sonication & Hydrodynamic)
- TiO_2 – Catalyzed UV Oxidation
- Ex Situ Fenton's Reaction

Two Stage Process

1. Formation of strong oxidant



2. Reaction of oxidant with organic contaminant

$$\bullet OH + HCO_3 \rightarrow CO_3 + H_2O$$

Water Quality Impacts

- Alkalinity
- TOC & NOM
- Nitrates/Nitrites
- Phosphates/Sulfates
- Iron (II), Copper (I), Manganese (II)
- Turbidity

AOP Advantages / Disadvantages

Advantages	■ Destructive process ■ Disinfection capability ■ Established technology
Disadvantages	■ Oxidation byproducts ■ Bromate formation ■ Interfering compounds

Process Types

- Hydrogen Peroxide/Ozone (H_2O_2/O_3) process

$$H_2O_2 + H_2O \longleftrightarrow HO_2^- + H_3O^+$$
$$O_3 + HO_2 \longrightarrow \bullet OH + O_2^- + O_2$$

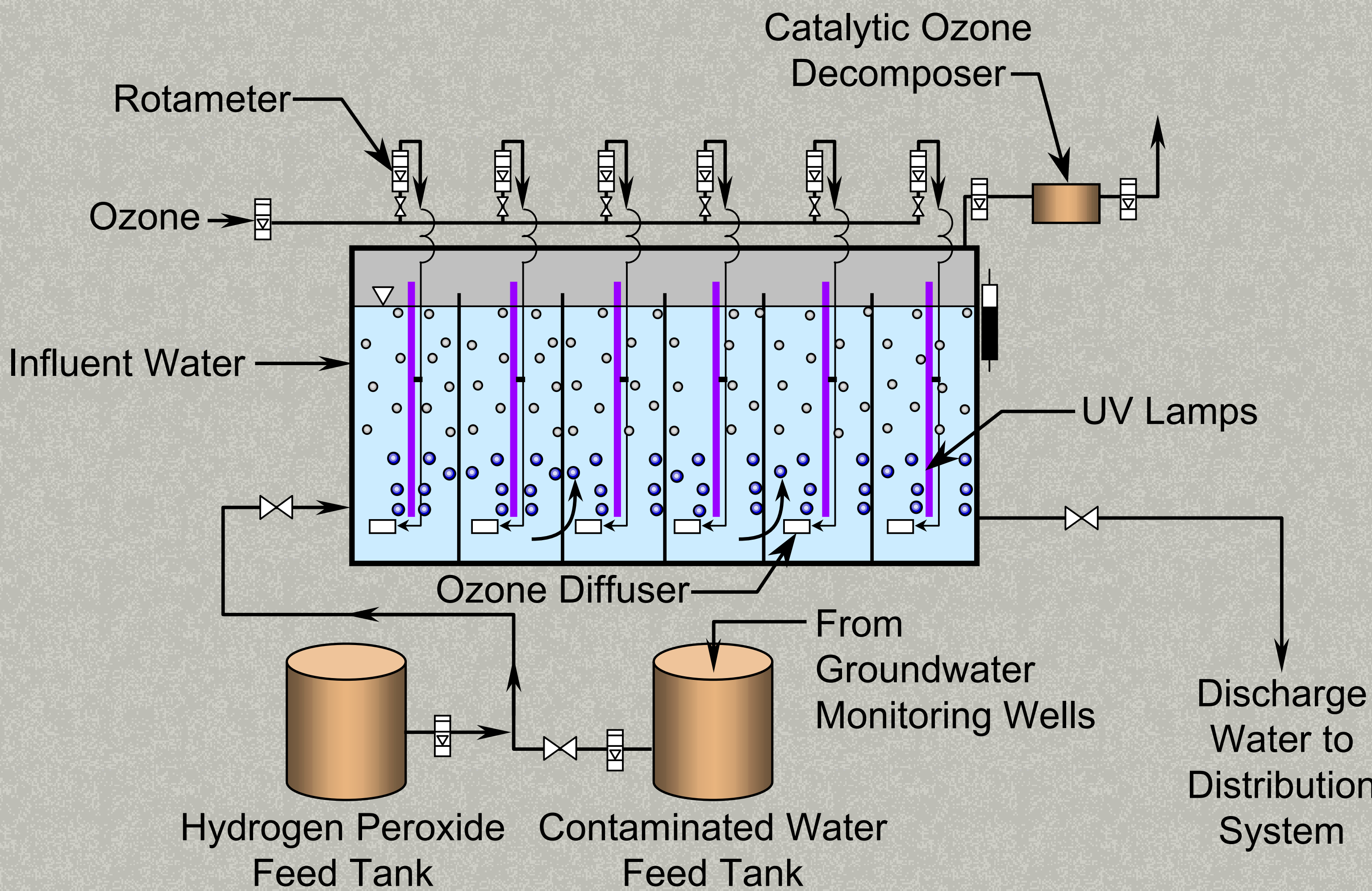
- Ozone/Ultraviolet Irradiation (O_3/UV) process

$$O_3 + HO_2 \longleftrightarrow O_2 + H_2O_2 \quad (\lambda < 300\ \text{nm})$$
$$2O_3 + H_2O_2 \longrightarrow 2 \bullet OH + 3O_2$$

- Hydrogen Peroxide/UV (H_2O_2/UV) Process

$$H_2O_2 \longrightarrow 2 \bullet OH \quad (\lambda < 300\ \text{nm})$$

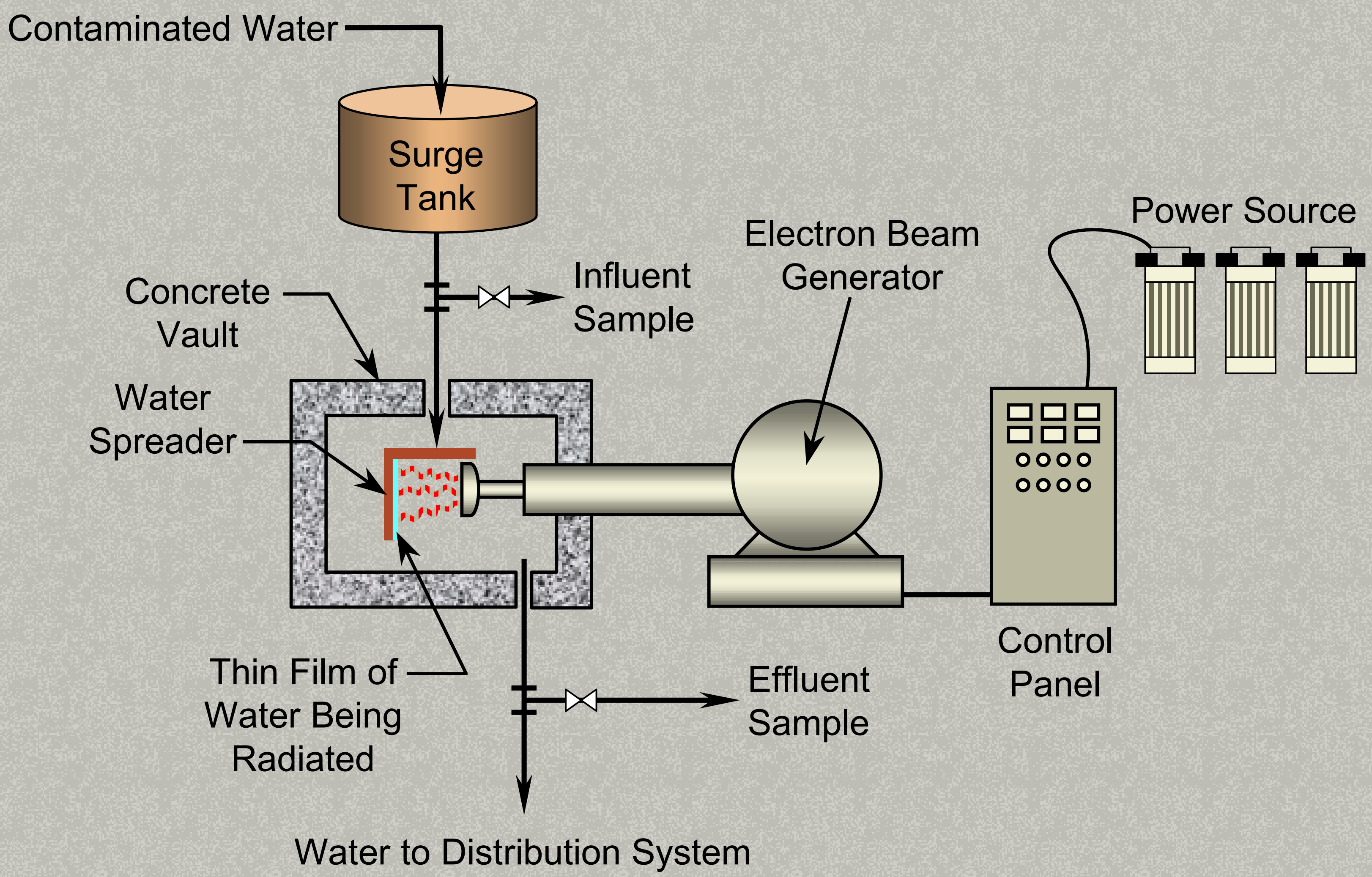
(H_2O_2/O_3) Process Schematic



E-Beam

- Ionizing radiation from an electron beam source is used to initiate changes in aqueous contaminants.
- E-beam radiation is absorbed almost completely by target compounds in their electron orbitals, thereby changing the molecular structure of the compound.
- Typically used in food and beverage industry for disinfection.
- Little potential for byproduct formation and water quality typically has minimal effect.
- Energy-intensive and may ultimately prove to be cost-prohibitive.
- Public stigma of radiation.

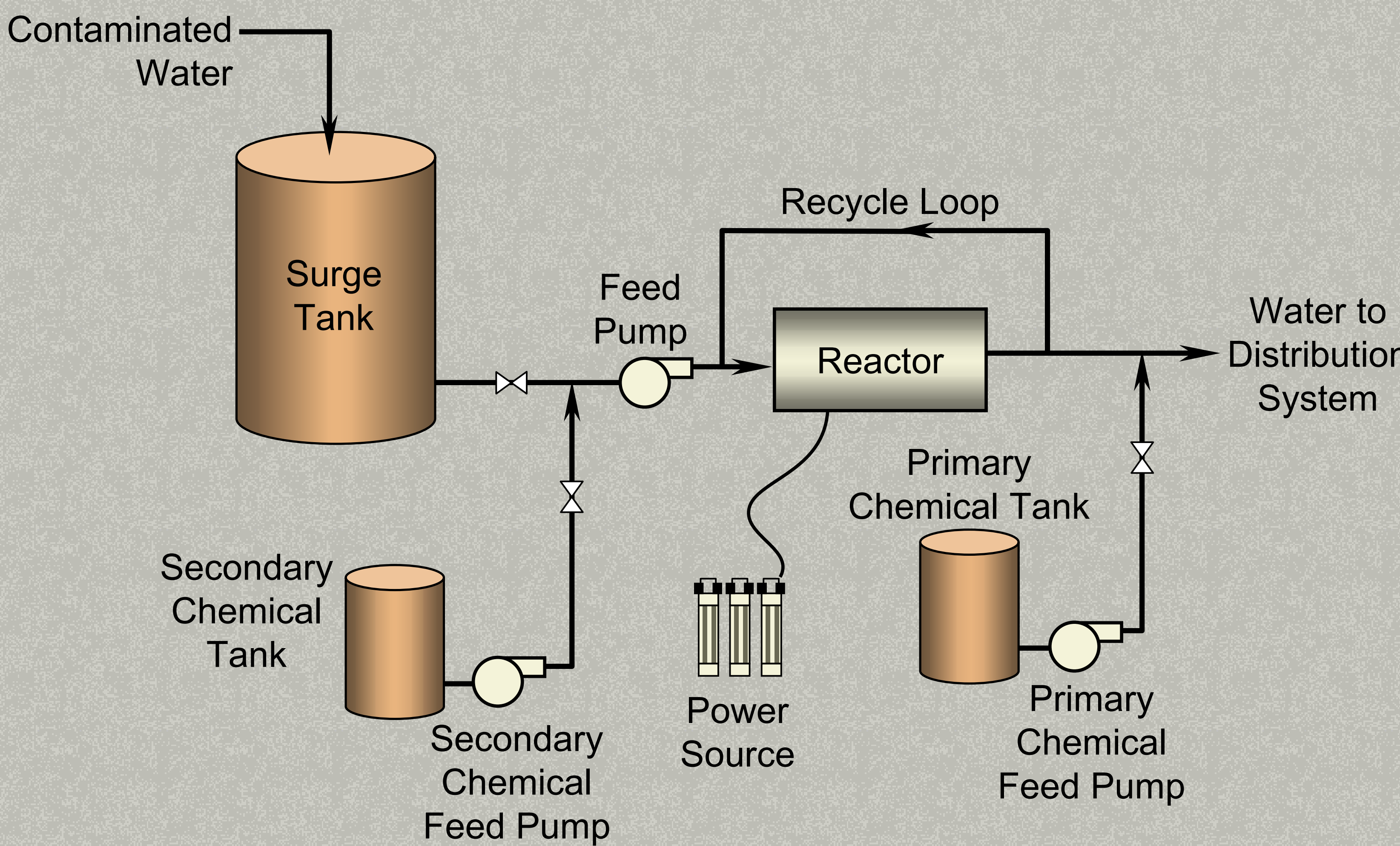
E-Beam Process Schematic



Cavitation

- Formation of microbubbles in solution that implode violently after reaching critical resonance size.
  - The rapid implosion of microbubbles results in high temperatures at the bubble/water interface causing thermal decomposition of contaminants or decomposition of water into OH and H radicals.
- Three methods include ultrasonic irradiation, pulse plasma cavitation, and hydrodynamic cavitation.
  - Ultrasonic produces microbubbles by sequencing ultrasonic frequency cycles.
  - Pulse plasma uses high voltage discharge through water.
  - Hydrodynamic cavitation uses high-velocity or pressure gradients.
- Process uses additional oxidants O_3 and H_2O_2.
- Hydrodynamic cavitation is a black box technology.
- No full-scale applications to date.

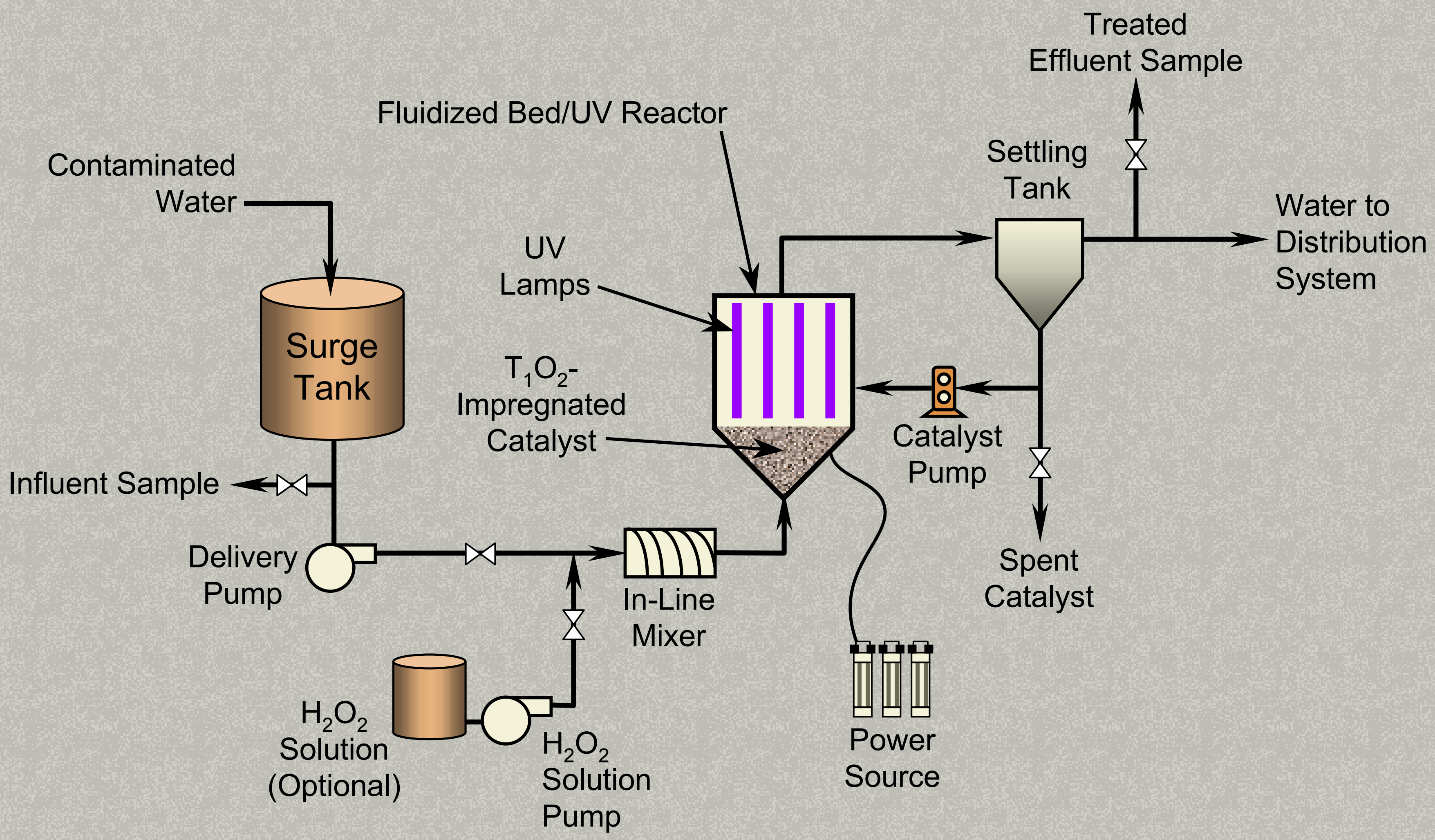
Cavitation Process Schematic



TiO_2 – Catalyzed UV Oxidation

- TiO_2, a solid metal catalyst, is illuminated by UV lights (380 nm) to create an excited state of electrons, thereby initiating a wide range of chemical reactions including formation of hydrogen peroxide and OH radicals.
- Subject to radical scavengers affecting other AOPs.
- pH must be controlled to minimize fouling of TiO_2 by dissolved anions and cations, and may require pretreatment by ion exchange.
- No full-scale applications in operation.
- Need for TiO_2 catalyst could be high depending on water characteristics competing for TiO_2 active sites (NOM, inorganics, metal cations).

TiO_2 Process Schematic



Fenton's Reaction

$$Fe^{2+} + H_2O_2 \longrightarrow Fe^{3+} + OH^- + OH\bullet$$

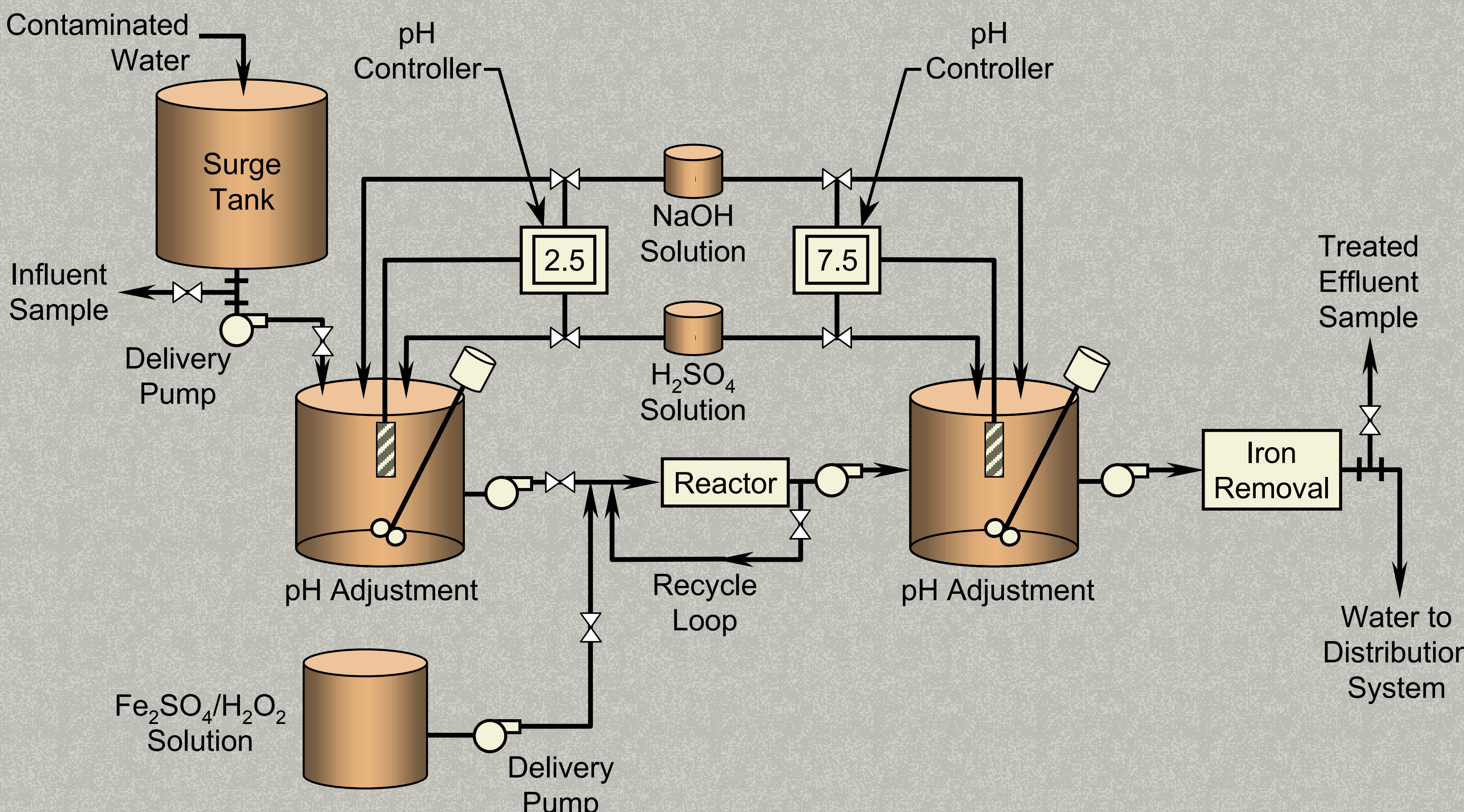
****

$$Fe^{3+} + H_2O_2 \longrightarrow Fe^{2+} + {}^*O_2 + 2H^+$$

$$O_2^- + Fe^{3+} \longrightarrow Fe^{2+} + O_2$$

- Process requires little energy compared to the AOPs.
- No vapor emissions.
- No full-scale ex situ applications to date.
- Need to remove excess iron from treated water.
- pH <2.5 needed to keep iron in solution.

Fenton's Process Schematic



Comparative Analysis of Various AOPs

AOP Technology	Reliability		Flexibility	Adaptability	Potential for Modifications
	Mechanical	Process			
H_2O_2/O_3	High	High	High	Medium	Low
O_3/UV	Medium	High	High	Low	Low
H_2O_2/UV	Medium	High	High	Low	Medium
E-beam	Low	Low	Low	High	High
Hydrodynamic Cavitation	Medium	Low	Low	High	Medium
TiO_2-Catalyzed UV Oxidation	Low	Medium	Medium	Medium	Low
Fenton's Reaction	Low	Medium	Medium	Medium	Low

Comparative Analysis of Various AOPs (cont.)

AOP Technology	Bromate Regulatory Compliance	Energy Efficiency	Public Acceptance	Ease of Implementation
H_2O_2/O_3	Low-Medium	Medium	High	High
O_3/UV	Low	Low	High	High
H_2O_2/UV	High	Medium	High	High
E-beam	High	Low	Low	Medium
Hydrodynamic Cavitation	High	Medium	Low	Medium
TiO_2-Catalyzed UV Oxidation	High	Medium	Low	Low
Fenton's Reaction	High	High	Low	Low

AOP Capital Costs

MTBE Removal

Flow (gpm)	H_2O_2/UV ($K)	H_2O_2/O_3 ($K)	Cavitation/H_2O_2 ($K)	TiO_2/H_2O_2 ($K)
60	177 – $266	144 – 622	134 – 260	277 – 691
600	266 – 1,300	1,666 – 1,888	356 – 482	1,142 – 3,092
6,000	1,000 – 10,000	8,000 – 9,775	1,446 – 4,339	9,711 – 26,288

AOP O&M Costs

MTBE Removal

Flow (gpm)	H_2O_2/UV ($K)	H_2O_2/O_3 ($K)	Cavitation/H_2O_2 ($K)	TiO_2/ H_2O_2 ($K)
60	54 – 108	47 – 64	60 – 75	74 – 107
600	157 – 551	123 – 222	167 – 239	265 – 483
6,000	930 – 4,210	464 – 1,351	1,101 – 1,725	2,389 – 4,505

Case Study – Vineland, NJ

Problem:

Vineland Chemical Co. manufactured organic arsenical herbicides and fungicides from 1949 to the early 1990s.

- Objective was to treat the groundwater to total arsenic concentration of 10 ppb.
- Previous studies found arsenic in the 1,000-2,000 ppb range treatable by coagulation and filtration.
- New water quality data showed organic arsenic concentrations in range of 123,000 ppb monomethylarsenate, with total arsenic concentrations of 210,000 ppb.

Case Study – Vineland, NJ

Monomethylarsenate	41 ppb
Dimethylarsenate	5.6 ppb
As^{+3}	1,637 ppb
As^{+5}	1,023 ppb

Peroxide (H_2O_2) alone treated to 200-500 ppb range. H_2O_2/UV with coagulation and filtration achieved desired effluent quality of 10 ppb.

Case Study – Johnson & Johnson, Puerto Rico

- Objective was to develop a new wastewater management strategy for an integrated sanitary, utilities, and process wastewater treatment system.
- J & J discharges wastewaters to PRASA Humaco wastewater treatment plant and has limits on mass loads they can discharge.
- Treatment objective was to reduce COD from 3,000 ppm to 350 ppm.

Case Study – Johnson & Johnson, Puerto Rico

J&J Consumer products facility wastewater treatment objective: 350 ppm

	Oxidation Time (minutes)						
	0	**5**	**10**	**15**	**20**	**25**	**30**
COD (ppm)	5,200	4,300	3,500	2,600	900	280	150

H_2O_2 Dosage 2,000 ppm; pH – 4.7

Case Study – Johnson & Johnson, Puerto Rico (cont.)

Full-Scale Treatment Conditions

Flowrate (Q)	7 gpm
COD	3,000 ppm
CODe	350 ppm
Oxidation Time	7.4 min
Power Demand	207 kW
H_2O_2 Dosage	730 lb/day
Muriatic Acid	25 lb/day

Case Study – Johnson & Johnson, Puerto Rico (cont.)

Summary:

H_2O_2/UV successfully treated high organic COD load of 5,200 ppm to desired effluent quality.

Costs

- Capital: $650 – 800K
- O&M: $40 – 50K

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- Definition
- Oxidation Processes
- Biotreatment Processes
- Design & Operation Considerations
- Case Study

Biological Treatment

Definition

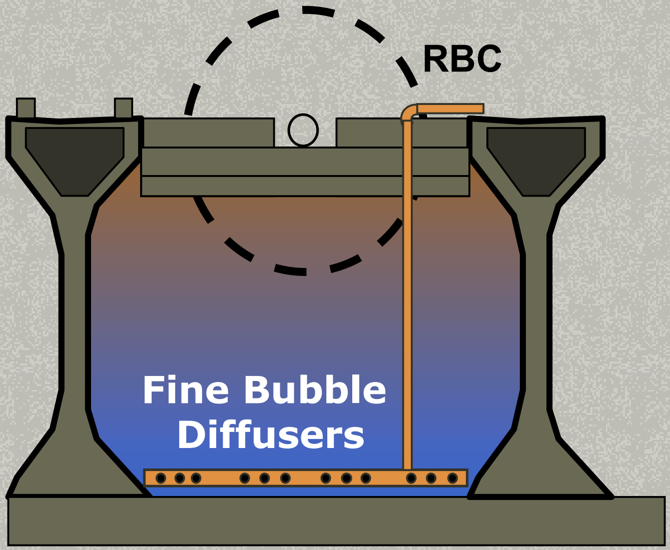
- The conversion of organic matter to inorganic end products and cell tissue via aerobic, anaerobic, or facultative, suspended, or attached growth systems.

Biological Oxidation Process

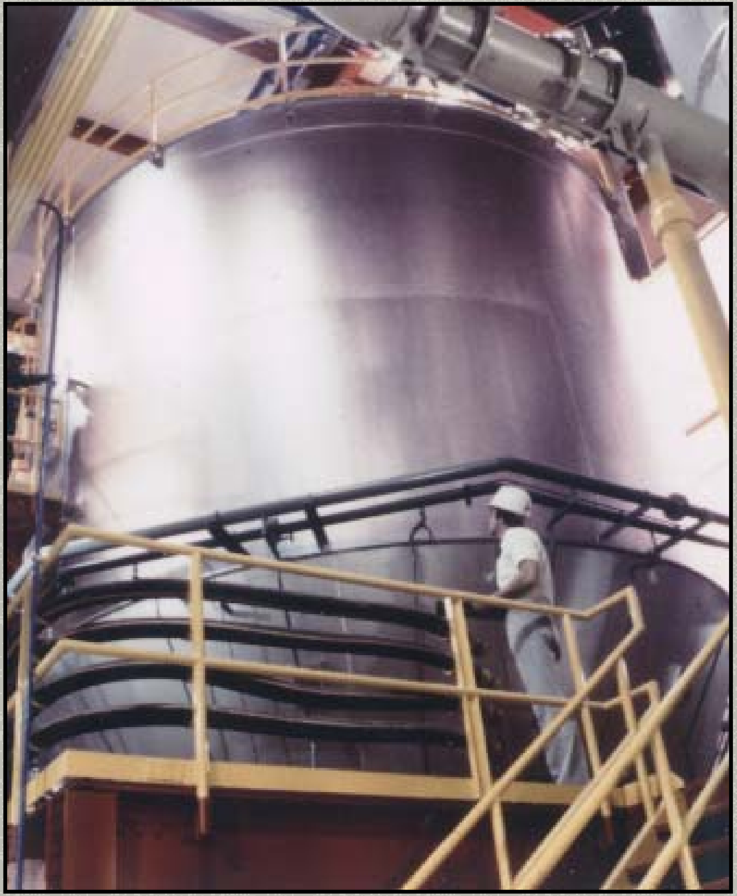
$$\text{Organic Matter} + O_2 + \text{bacteria} \longrightarrow CO_2 + NH_3 + H_2O$$

Biotreatment Processes – Fixed Film

Rotating Biological Contactor (RBC)



Biotreatment Processes – Suspended Growth



Fluidized Bed (FBR)

Activated Sludge

Design & Operation Considerations

- Hydraulic loading
  - Must control to minimize scouring of biomass in fixed film systems.
- Food:Mass ratio
  - High F:M (>0.7) results in incomplete metabolism of organic matter.
  - Low F:M (<0.7) bugs near starvation results in good organic treatment.
- Organic loading – BOD/N/P ratio of 100/5/1
- Dissolved oxygen – >2 ppm
- pH – 6.5-8.5

Advantages/Disadvantages

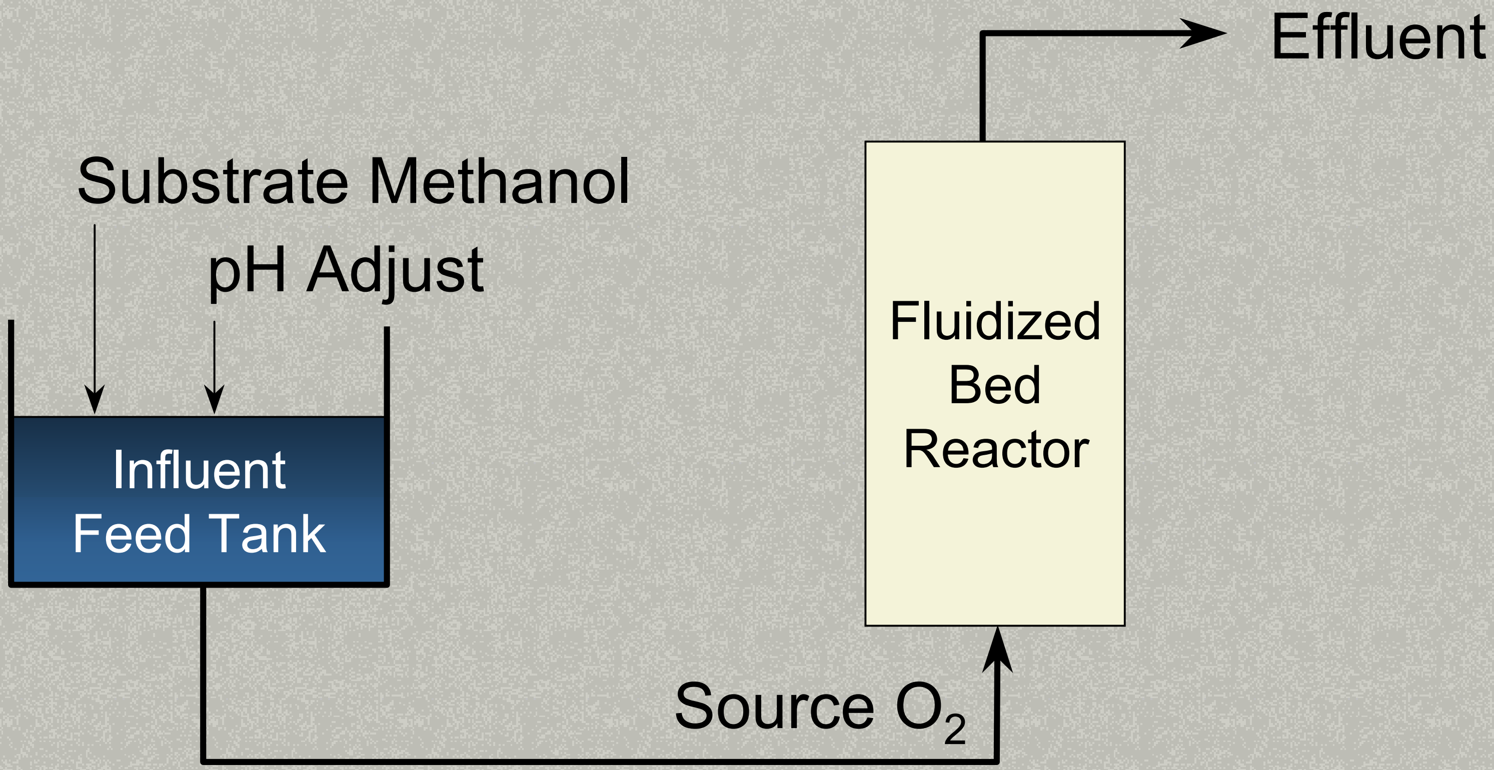
Advantages	▪ Can handle high organic load compared to GAC. ▪ Not affected by dissolved inorganics. ▪ Microbes can be cultured for specific contaminants.
Disadvantages	▪ Metals and SOCs in high concentrations could be toxic to microbes. ▪ Increased operational responsibilities. ▪ Not suitable for waste stream with varying waste load.

Case Study – VAAP Chattanooga, TN

- Volunteer Army Ammunition Plant (VAAP) manufactured up to 16,000 lb of TNT during war time activities. Nitrotoluene, used during production, and production byproducts contaminated site groundwater.
- Pilot system proposed for use was fluidized bed reactor (FBR) capable of treating flows of 20-30 gpm.
- Site hydrology could only deliver 1-3 gpm.
- Demonstration project of FBR treatment of TNT and DNT was conducted in field with low-flow system to develop system design criteria for FBR treatment at other DoD sites.

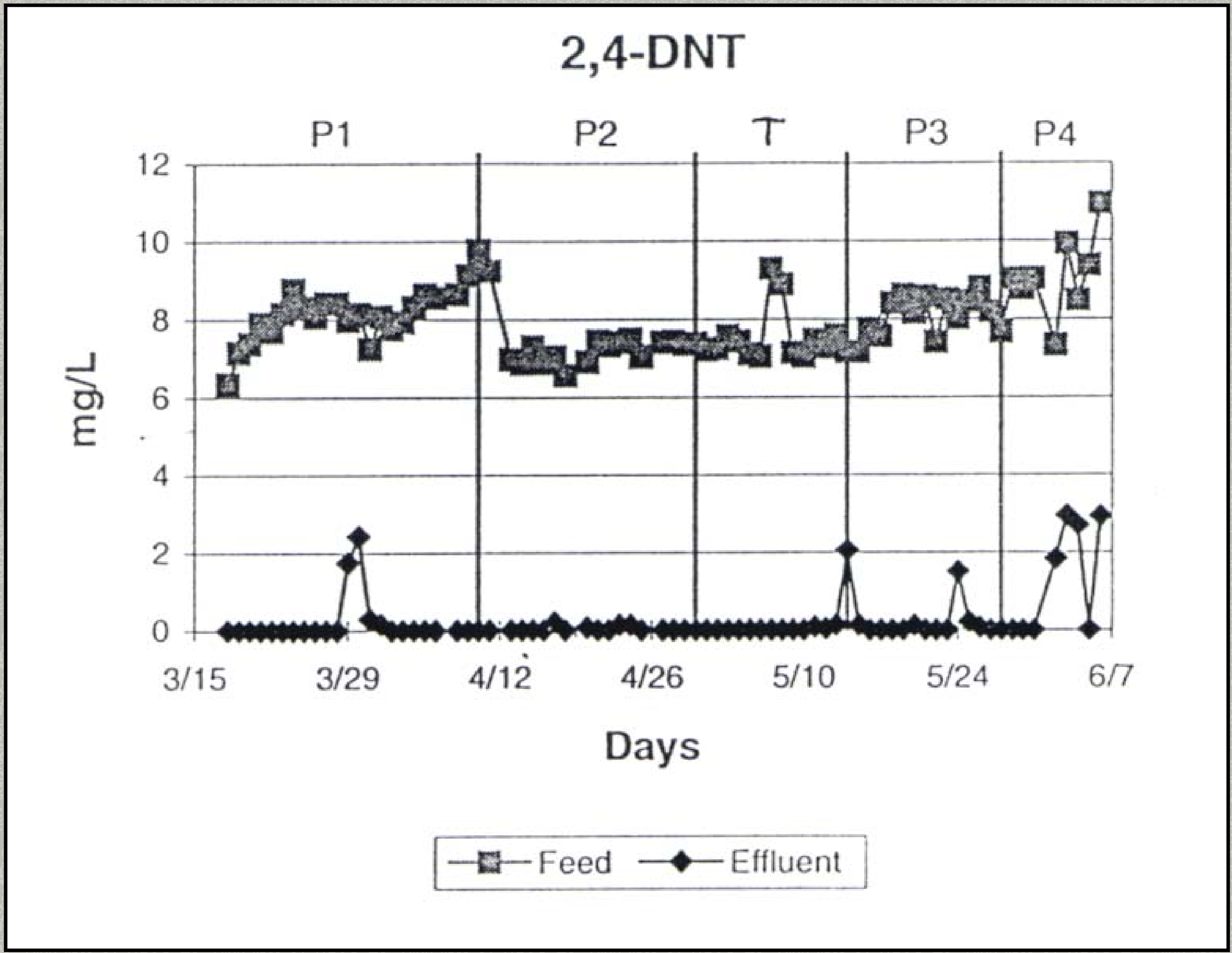
Case Study – VAAP Chattanooga, TN

FBR Schematic

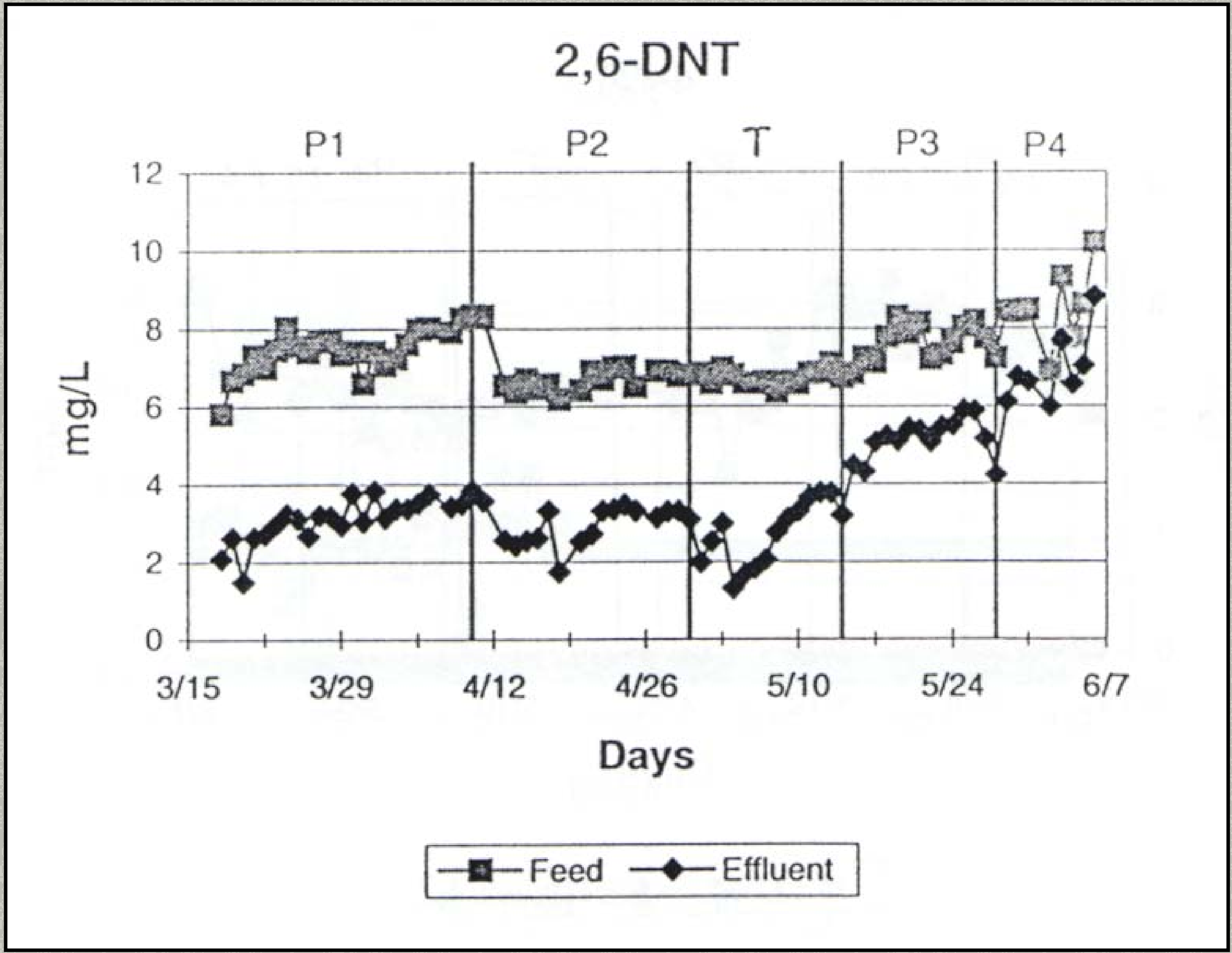


Case Study – VAAP Chattanooga, TN

Case Study – VAAP Chattanooga, TN



Case Study – VAAP Chattanooga, TN



FBR Comparison Costs

Capital, O&M, and NPV Cost Comparison for Case 1 (30 gpm, 37 lb/day NT)

Technology	Installed Capital Cost[1]	O&M Costs[2]	NPV Cost[3]
FBR System	$300,000	$40,581/yr $2.57/1,000 gal $3.02/lb	$598,006 $3.79/1,000 gal $4.45/lb
UV/Ozone	$601,880	$57,548/yr $3.65/1,000 gal $4.29/lb	$1,000,649 $6.35/1,000 gal $7.46/lb
LGAC	$100,825	$60,447/yr $3.83/1,000 gal $4.50/lb	$519,319 $3.29/1,000 gal $3.87/lb

[1] Does not include one-time startup and training cost.

[2] Includes costs for commercial waste disposal for FBR, but does not include cost for spent GAC disposal (from FBR) at end of project.

[3] 10-year project life: 4% interest/inflation rate; 12% discount rate. Includes one-time startup and training cost and cost for spent GAC disposal (from FBR) at end of project.

FBR Cost Comparison (cont.)

Capital, O&M, and NPV Cost Comparison for Case 2 (100 gpm, 122 lb/day NT)

Technology	Installed Capital Cost[1]	O&M Costs[2]	NPV Cost[3]
FBR System	$694,000	$107,916/yr $2.05/1,000 gal $2.41/lb	$1,489,321 $2.83/1,000 gal $3.33/lb
UV/Ozone	$1,090,600	$137,437/yr $2.61/1,000 gal $3.07/lb	$2,033,911 $3.87/1,000 gal $4.55/lb
LGAC	$252,970	$184,978/yr $3.52/1,000 gal $4.13/lb	$1,519,760 $2.89/1,000 gal $3.40/lb

[1] Does not include one-time startup and training cost.

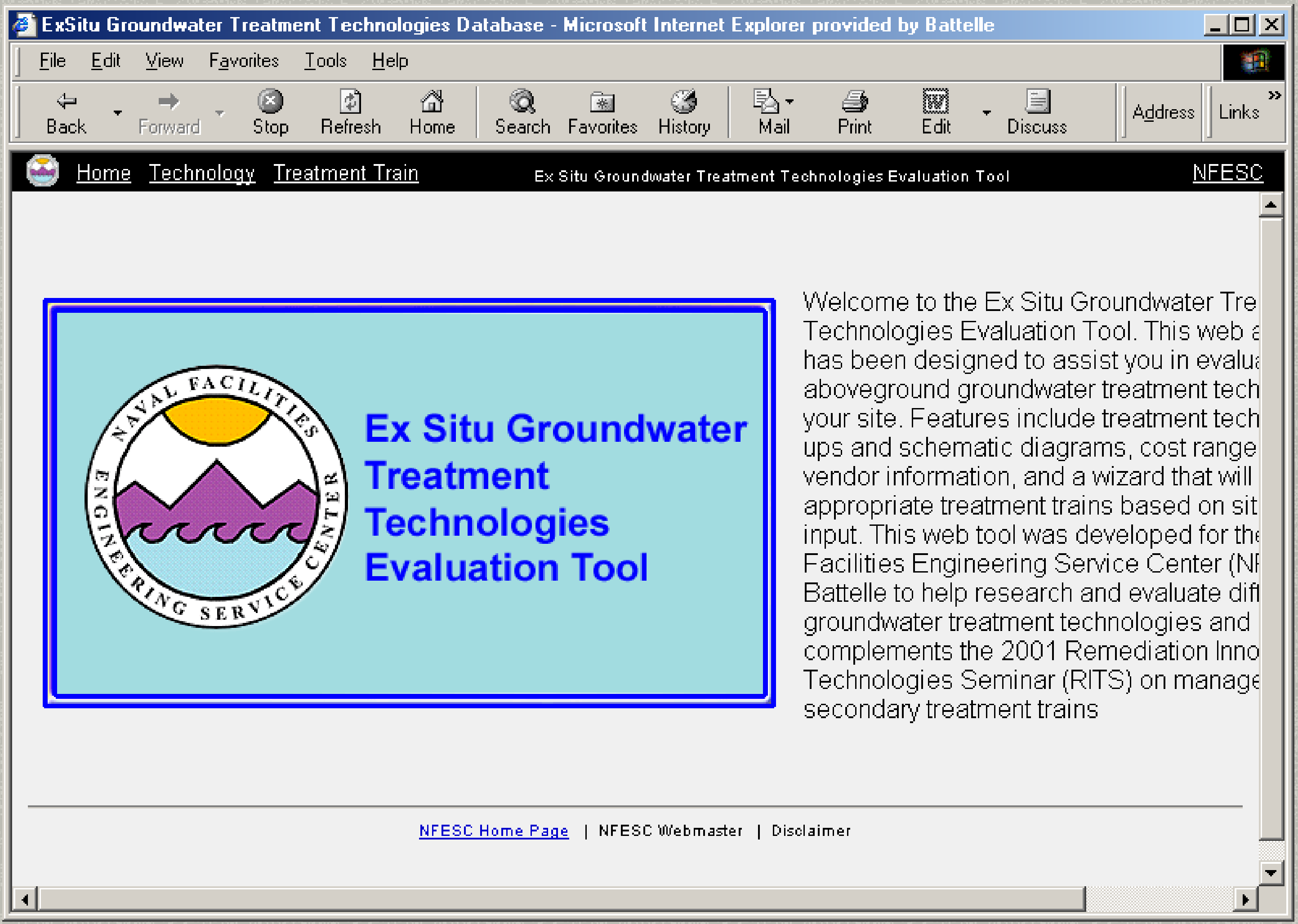
[2] Includes costs for commercial waste disposal for FBR, but does not include cost for spent GAC disposal (from FBR) at end of project.

[3] 10-year project life: 4% interest/inflation rate; 12% discount rate. Includes one-time startup and training cost and cost for spent GAC disposal (from FBR) at end of project.

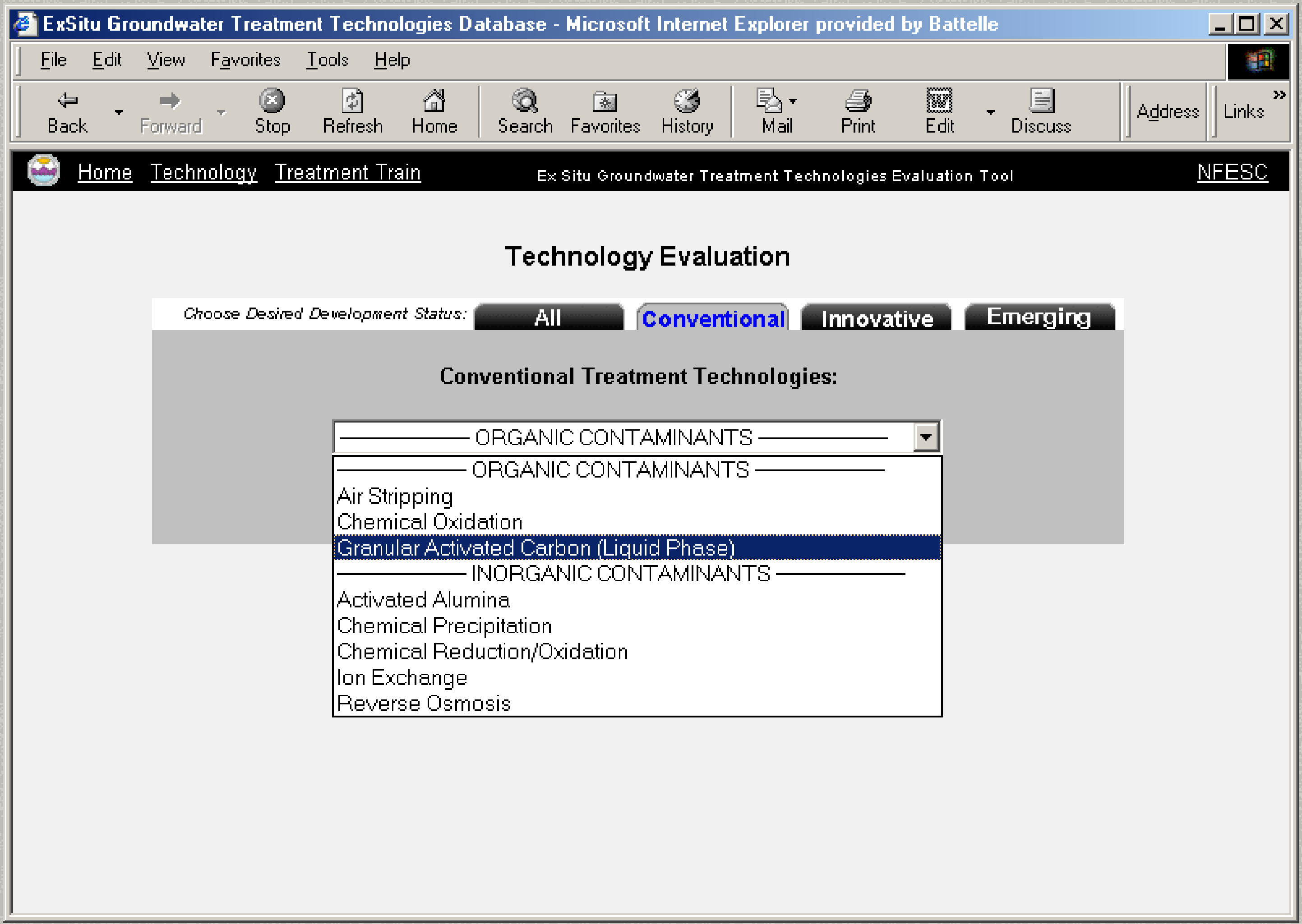
Summary

- Know your water chemistry.
- Consider post-treatment chemistry.
- Use treated effluent requirements to drive treatment selection and design.
- Consider using multiple processes, phasing unit processes out as groundwater is remediated.
- Determine what ancillary processes may be needed to provide effective treatment.
- Beware new-emerging black box technologies.
- Understand site hydrogeology.

http://enviro.nfesc.navy.mil/erb/erb_a/restoration/technologies/sel_tools/secondary/default.asp



Select Treatment Technology



View Typical Costs

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Technology Evaluation

Choose Desired Development Status: All | Conventional | Innovative | Emerging

All Treatment Technologies:

Granular Activated Carbon (Liquid Phase)

Typical Cost for Granular Activated Carbon (Liquid Phase)

	Approximate Cost		
Flow Rate (gpm)	Capital (K$)	Annual O&M (K$)	Unit Cost ($/1000 gal)
60	75-3,215	50-1,158	3.45-57.30
600	301.8-12,800	127-2,910	1.14-19.01
6000	1,200-50,955	676-7,310	.48-6.62

Technology Profile | View Schematic | Pros & Cons

Vendors for Granular Activated Carbon (Liquid Phase)

Compare Vendors

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Systems for Granular Activated Carbon (Liquid Phase) Technology:

ResinTech, Inc.

Envirotrol, Inc.

Liquid-miser

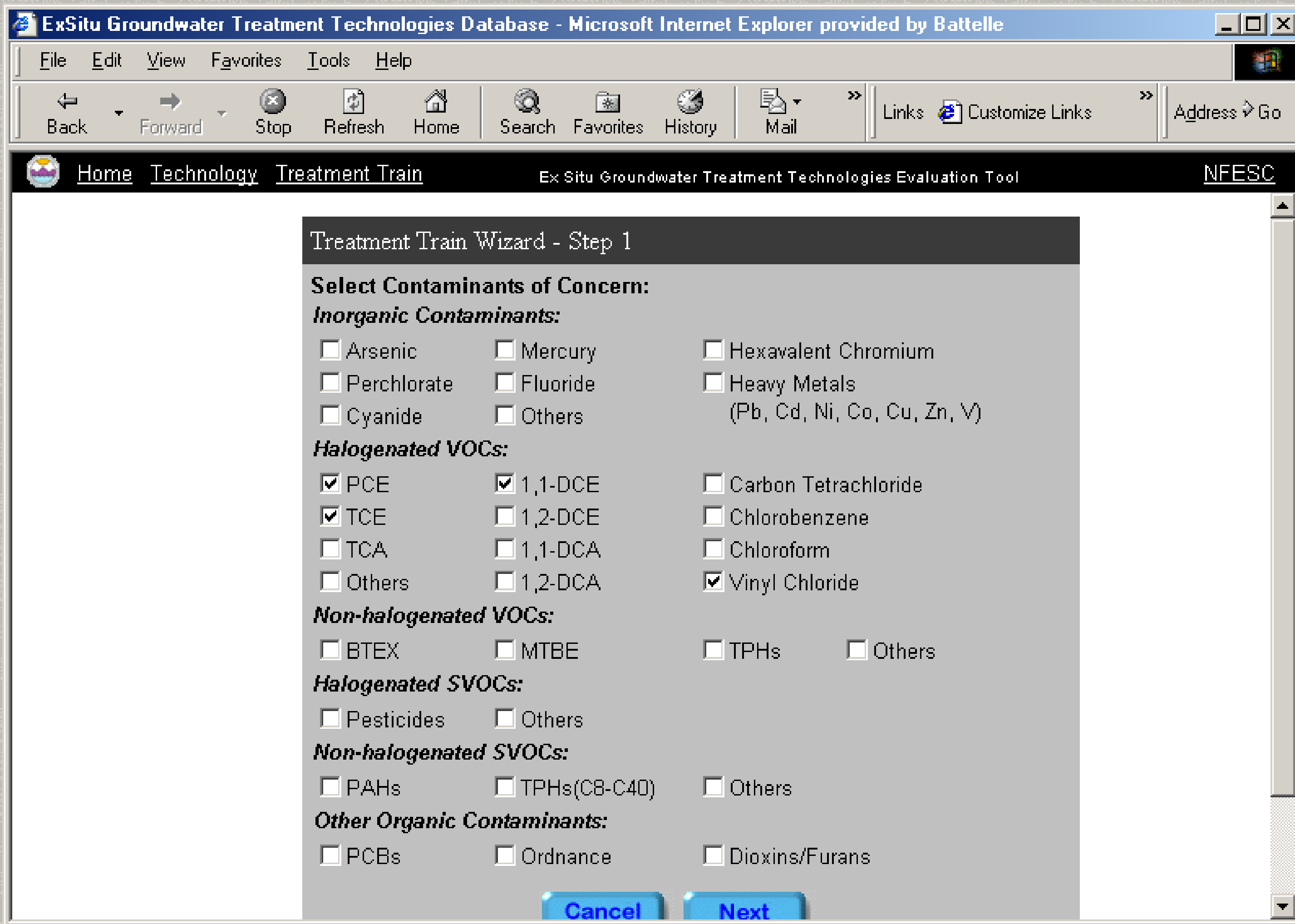
USFilter

Cansorb, Nixtox

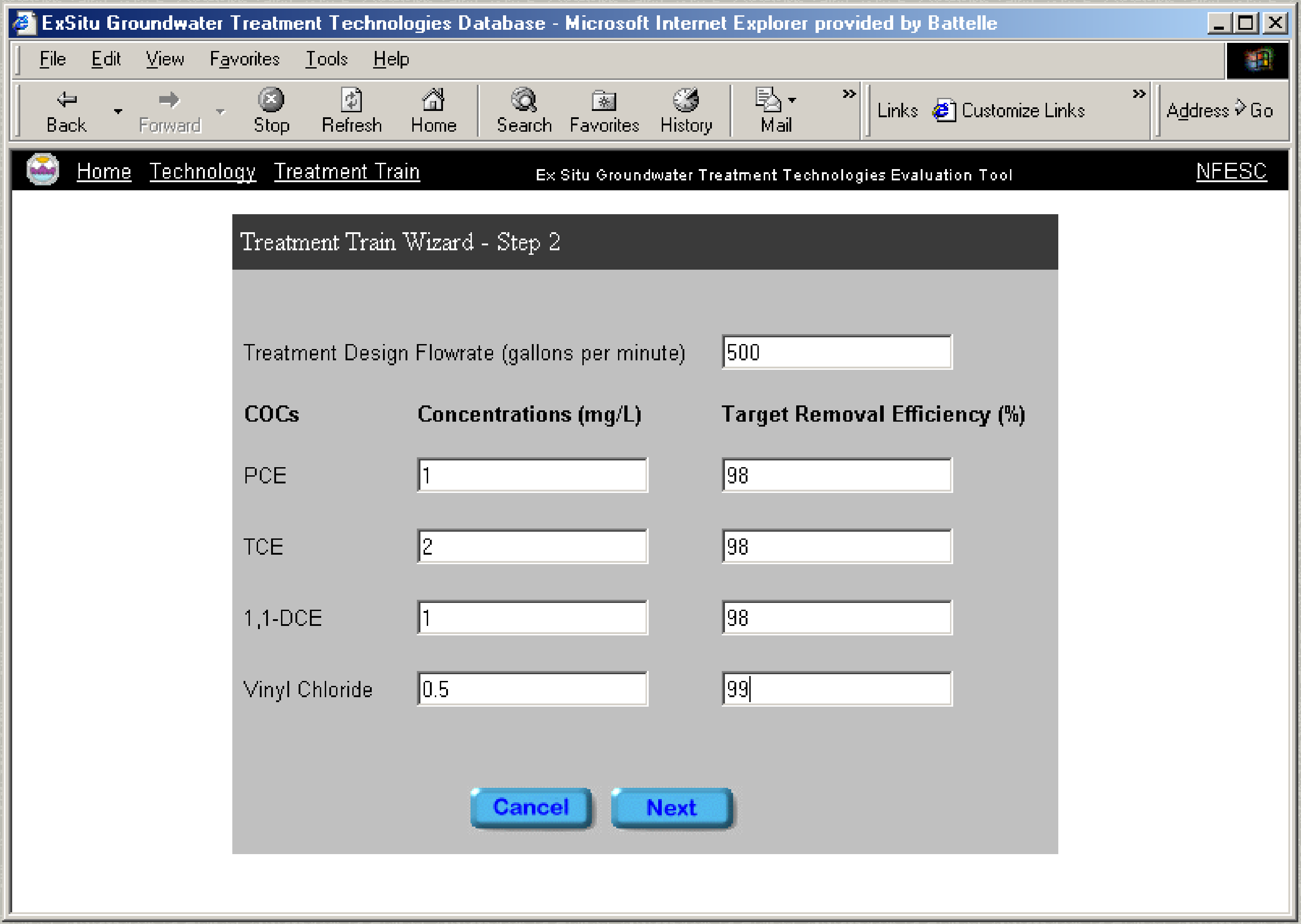
Technology: Granular Activated Carbon (Liquid Phase)
System: Envirotrol, Inc.

Destruction Removal Efficiency	90-100%
Unit Cost Range	$1.00-$3.00/1000 gallons
Inlet Concentration Limit	0.50-50,000 ppm
System Capacity	5-6,000 gpm
Subcomponents	Not Available
# Units Installed	Not Available
HAZ Waste Generated	Spent GAC
Vendor(s)/Contact(s)	info@envirotrol.com Envirotrol, Inc. (412)741-2030 (412)741-2670 (Fax) P.O. Box 61, 432 Green St. Sewickly, PA 15143 www.envirotrol.com

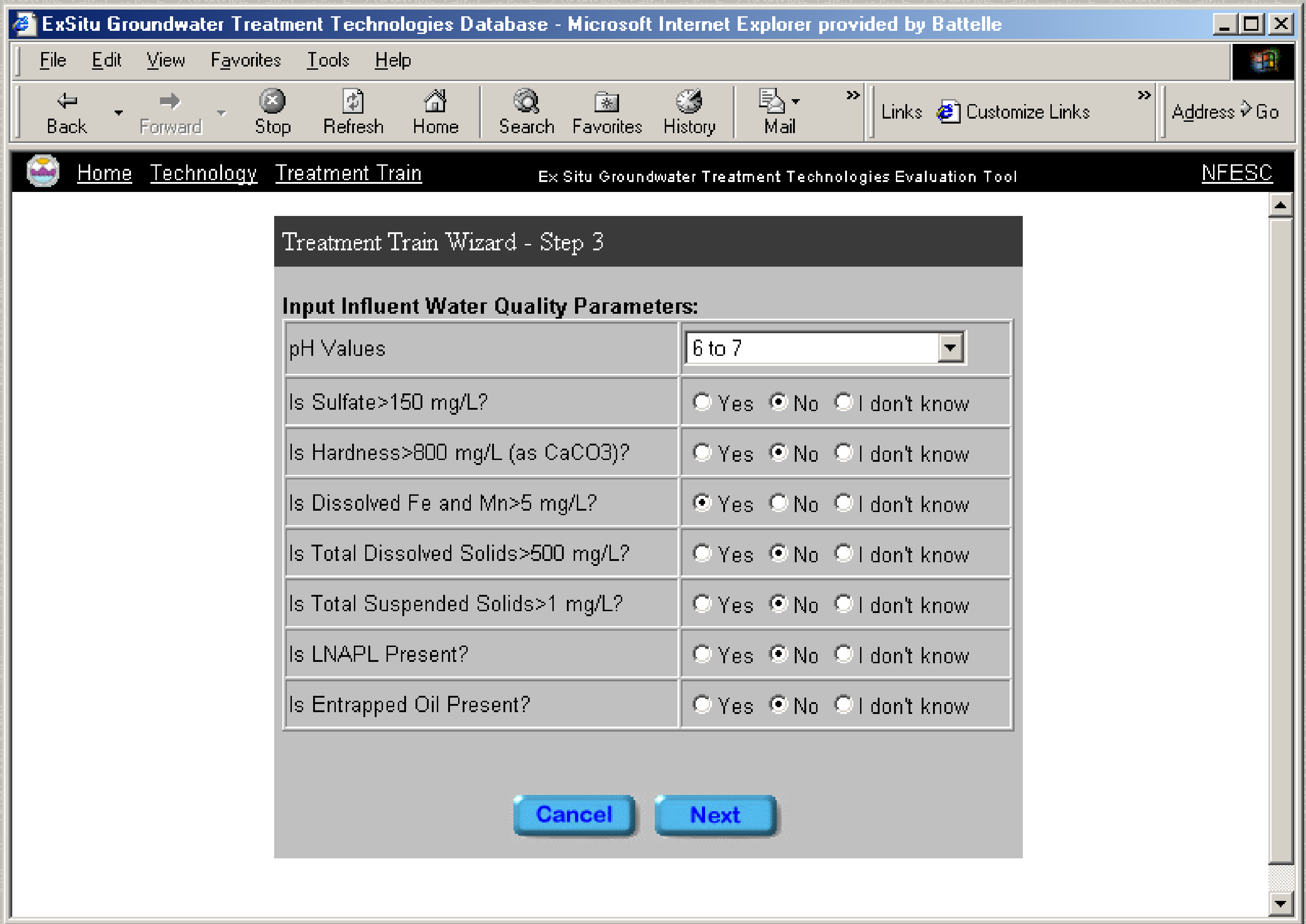
Select Site COCs



Enter Site-Specific Variables



Input Influent Water Quality Parameters



View Evaluation

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Ex Situ Groundwater Treatment Trains

Treatment Train	Tech ID	Primary Treatment	Type	Oil/Water Separation	Water Quality Adjustment	Inorganics Polishing	Organics Polishing	Post Treatment
1	1	Air Stripping	O	None	Fe/Mn Removal	None	GAC	None
2	5	Chemical Oxidation	O	None	Fe/Mn Removal	None	None	None
3	12	UV Oxidation	O	None	Fe/Mn Removal	None	None	None
4	3	Bioreactor	O	None	Fe/Mn Removal	None	None	None
5	6	Constructed Wetland	O	None	Fe/Mn Removal	None	None	None

References

- "*Treatment Technologies for Removal of Methyl Tertiary Butyl Ether (MTBE) from Drinking Water: Air Stripping, Advanced Oxidation Processes, Granular Activated Carbon, Synthetic Resin Sorbents*," 2nd Edition; February 2000.
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- Montgomery, James M., "*Water Treatment Principles and Design*." John Wiley & Sons, (1985).
- Riznychok, W. M., "*Air Stripping of VOCs from Sanitary and Industrial Effluents*," December 1982.
- Hammer, Mark J., "*Water and Waste-Water Technology*," John Wiley & Sons, Inc., (1975).